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Cincinnati, OH

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LAWRENCE AVENUE UNDERFLOW SEWER SYSTEM
Monitoring and Evaluation

by

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City of Chicago
Department of Public Works
Chicago, IL 60610

EPA Grant S807116
(Formerly 11020 EMD)

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16. ABSTRACT

A new and bold concept in design of urban drainage systems was developed as a step forward in the solution of combined sewer overflow problems. A deep tunnel in bed rock about 200 to 250 feet (61 to 76 m) below the surface was designed and constructed for the Lawrence Avenue drainage basin in Chicago. Flows and pollutants to the river and treatment plant were monitored. Performance of the tunnel system in capturing flows and pollution was evaluated with the help of calibrated computer models. Groundwater was monitored to assess the project influence on the aquifer. The results show that this design is very effective in reducing combined sewer overflows to the waterway. Tunnels capture smaller storms, and trap a significant portion of the first flush of pollutants from larger storms which is subsequently pumped to the treatment plant. Use of modern tunnel boring machines makes this design economically competitive with conventional sewers while reaping additional benefits of ease in construction, no disturbance to traffic and least inconvenience to Public.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous wastes pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

Many of our cities are faced with pollution problems associated with combined sewer overflows. Reduction or elimination of combined sewer overflows into the receiving waters require some kind of storage and treatment facilities at considerable costs, particularly in large cities where land is scarce. Construction of deep rock tunnels to serve as main outlets for the combined sanitary and storm flow offers an attractive means of minimizing this problem. The sewer, being below the river level, provides storage and captures a large portion of the pollution from combined sewers. The construction of such a tunnel system results in the elimination of surface restoration costs. Moreover, the inconvenience to general public by disruption of streets, utilities, sidewalks, etc. and interference with commercial activity is completely avoided. The planning, design and construction of such a deep tunnel by the City of Chicago for their Lawrence Avenue drainage basin was described in the USEPA Publication No. EPA-600/2-80-124 dated March 1980 entitled "Lawrence Avenue

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Underflow Sewer System, Interim Report - Planning and Construction". This Final Report describes the monitoring of the combined sewer flows to the river and the treatment plant, monitoring of the quality of groundwater in the project vicinity and evaluation of the performance of the Lawrence Avenue Underflow Tunnel System in reducing overflows and pollution to the waterway.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

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ABSTRACT

A new and bold concept in design of urban drainage systems was developed as a step forward in the solution of combined sewer overflow problems. A deep tunnel in bed rock about 200 to 250 feet (61 to 76m) below the surface was designed and constructed for the Lawrence Avenue drainage basin in Chicago. The tunnel also serves as a reservoir capturing smaller storms, and trapping a significant portion of the first flush of pollutants from larger storms. The entrapped combined sewage is pumped to the treatment plant at the end of each storm.

Details of planning, design and construction, including hydraulic model studies performed for design of dropshafts were described in the Interim Report mentioned in the Forword.

Flows and pollutants to the river and treatment plant from selected outfalls in the Lawrence Avenue drainage basin were monitored. USEPA's Storm Water Management Model was calibrated with the measured data. Performance of the tunnel system in capturing flows and pollution was evaluated with the help of the calibrated model. Groundwater monitoring was conducted for preproject and postproject conditions and results analyzed to assess the influence, if any, of the deep tunnel system on the underground aquifer.

The results of the present study show that the use of deep rock tunnels in conjunction with a pumping station is a very effective means of reducing the spillage of combined sewer flows and pollutants to the waterway. Use of modern tunnel boring machines has improved the economics of the method. Deep tunnels reap additional benefits of ease in construction, no disturbance to traffic and least inconvenience to public.

This report is submitted in fulfillment of Demonstration Grant No. S807116 (Formerly 11020 EMD) of the U. S. Environmental Protection Agency covering the period of June, 1967 through September, 1981.

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Further thanks are given to Mr. Clifford Risley, Jr., Office of Research and Development, Region V, Mr. Richard Field, Chief, Mr. Richard P. Traver and Mr. Douglas C. Ammon, Staff Engineers, Storm & Combined Sewer Section, all of the U.S. Environmental Protection Agency, for their cooperation and assistance.

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SECTION I

CONCLUSIONS

For the sake of completeness the conclusions listed below are based on the entire study, although a part of this was already documented in the Interim Report published in March 1980.

1. The Lawrence Avenue Underflow Sewer System reduces the combined sewer overflow annual volume by 84 percent for an average hydrologic year. The annual mass load reduction in spillage of BOD and Suspended Solids into the waterway is 90 percent and 94 percent respectively as compared to preproject condition for an average hydrologic year.

2. The Lawrence Avenue System does not create any noticeable adverse effect on the quality of groundwater in the surrounding aquifer and does not cause any pollution hazard for the Wilson Avenue Water Tunnel.

3. With the recently improved technology in the field of tunneling, a rock tunnel sewer promises certain advantages over a large conventional open cut sewer. The former involves little interference with traffic, parking and commercial activity, least inconvenience to public, no hazards of accidental disruption of the numerous utility lines found in large cities and no costs of surface restoration.

4. Drilled tunnels utilizing rock boring machines (moles) are relatively smooth and need not be lined with concrete, if the rock is structurally sound and impermeable to exfiltration of polluted water into the aquifer. This would result in saving in lining costs and also add to the tunnel storage.

5. For dropping wet weather flow some 200 to 250 feet (61 to 76m) from high level sewers to the deep tunnel, the air entraining dropshaft of the Type E-15 (see Interim Report) was used for the Lawrence Avenue

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System on the basis of hydraulic model testing at the St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota. In the actual operation so far, these shafts have performed satisfactorily for the Lawrence Avenue Systems and other similar systems in Chicago.

6. For larger dropshaft the sloping crown of the air collection chamber requires huge excavations with associated high costs. Consideration should be given to reducing the size of the air chamber by venting air through a separate shaft wherever feasible. This was indicated by tests carried out later at the St. Anthony Falls Hydraulic Laboratory in conjunction with development of dropshafts larger than 9 foot (2.75m) diameter for the Tunnel and Reservoir Plan (TARP) for the Metropolitan Sanitary District of Greater Chicago. In the TARP design it has been found desirable to use a separately-vented dropshaft for sizes 12 feet (3.66m) or larger in diameter, and the divider wall in the dropshaft itself is thereby eliminated. This type of dropshaft, known as Type D-4, has a flat roof in the air collection chamber, which contractors find desirable for handling equipment, and the construction costs have been considerably less than for Type E-15 shafts to handle comparable flows.

SECTION II

RECOMMENDATIONS

As a result of the experience gained in the design, construction and evaluation of this pilot project and our work with the Sanitary District, particularly in the design of dropshafts for the TARP System, several recommendations can be made for future designs of this type. Some of these were also included in the Interim Report which should be referred to for details.

1. In metropolitan areas served by combined sewers, a deep rock tunnel system of the type described herein should be considered as an alternative to conventional relief sewers because of the avoidance of surface disturbance and the resulting inconveniences.

2. The tunneling should be carried out utilizing mining machines. The design should not call for frequent changes in tunnel sizes which should be in the range of available mole sizes.

3. Unlined tunnels approximately provide the hydraulic capacity of lined tunnels due to additional flow area provided by omission of lining. Therefore tunnel lining should be omitted if the rock strata are structurally sound and impervious.

4. For larger sizes the Type D-4 dropshafts with a separate vent shaft are recommended. The actual size would be governed by the economics of the specific situation.

5. It is preferable that the dropshaft structures and the pumping station and outfall be included in the same contract as the tunnel construction. This would give additional shafts for ingress and egress, and thus increase safety provisions. It would also give the contractor a greater number of locations where muck could be removed and would eliminate the interference of one contract with another.

6. A scale model of the pumping station and outfall should be provided by the designers as a check of the feasi-

bility of the design features (and thus reduce the possibility of construction problems) and as an aid to prospective bidders.

7. The Contractor should be required to keep the floor of the tunnel cleared of muck and debris. Also, a better drainage system in the tunnel should be required. In this tunnel, walking any great distance was extremely difficult because of poor housekeeping.

8. Recommendations for miscellaneous improvements in the design of a pumping station for an underflow sewer system are included in Section VII.

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SECTION III

INTRODUCTION

A. OBJECTIVE OF STUDY

The City of Chicago is located on a low plain adjacent to Lake Michigan at the mouth of the Chicago River near the Illinois-Indiana border. It comprises about 210 square miles (544 sq. kms.) of a combined sewered area of 375 square miles (971 sq. kms.) in the Chicago Metropolitan Area. Dry weather flow from the City is treated at three sewage treatment plants operated by the MSDGC (Metropolitan Sanitary District of Greater Chicago). These plants, the North Side, West-Southwest, and Calumet all discharge their effluent into the Chicago River System, as shown in Figure 1.

Storm and sanitary sewage is handled by combined sewers feeding interceptor systems leading to the various treatment plants. These interceptor systems are generally designed to carry twice the normal dry weather flow. During large storms, runoff in excess of interceptor capacity flows by gravity or is pumped to the river.

The City of Chicago has an ongoing program of building relief sewers, designated as "Auxiliary Outlet Sewers" to augment the discharge capability of the existing drainage system started better than a century ago.

The Lawrence Avenue Underflow Sewer System, designed in the late 1960's, is one such auxiliary sewer system built by the City of Chicago. Its innovative design utilizes deep rock tunnels for temporary storage as well as for conveyance of combined sewer flows. Being first of its kind in the nation, this project was provided a demonstration grant by the United States Environmental Protection Agency (USEPA), then called the Federal Water Pollution Control Administration (FWPCA).

The purpose of this study was to investigate and demonstrate the effectiveness of the aforementioned design concept in abatement of combined sewer overflows thereby reducing discharge of pollutants to the receiving waters and to document the knowledge acquired in the design, construction and operation of this pilot project.

The Department of Public Works of the City of Chicago has already completed an Interim Report dealing with the planning

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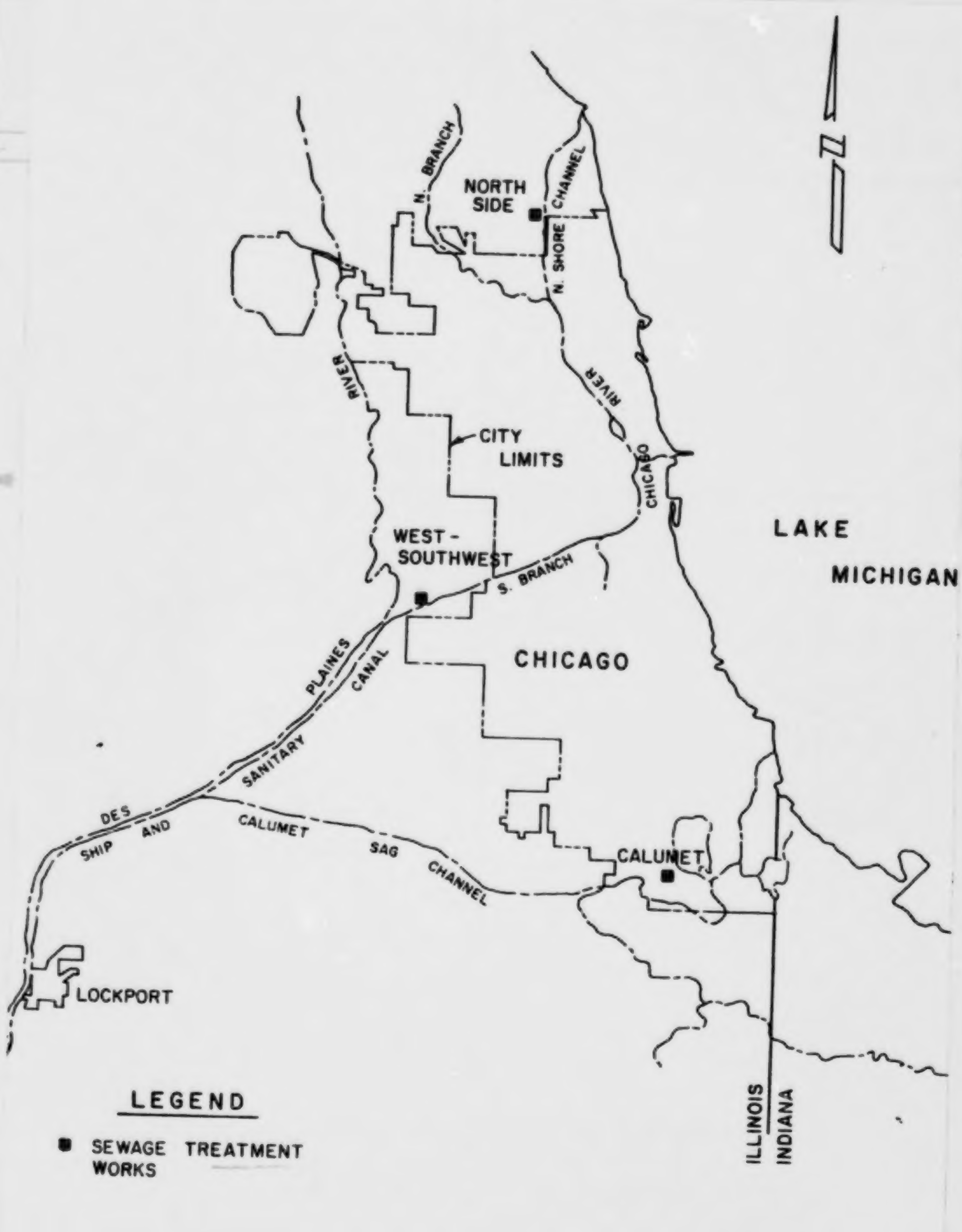
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CHICAGO
DES PLAINES
SHIP AND SANITARY CANAL
CALUMET SAG CHANNEL
CALUMET
LOCKPORT
ILLINOIS
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Figure 1. General Location Map.

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and construction details of the project. That Report was published by the USEPA in March 1980 as Publication Number EPA-600/2-80-014.

B. HISTORY OF PROJECT DEVELOPMENT

The history of the development of drainage and sewerage of the City of Chicago dates back to the early decades of the nineteenth century. The first sewers were constructed in the City about 1834, and in nearby communities that were independent, but later were annexed by Chicago. Since that time,the sewer system gradually expanded outward from the rivers and the lake. From the beginning, the type of drainage was that of "combined" sewers, conveying in the same conduit the combined flow of stormwater and household and industrial wastes. This was generally considered, by most cities at that time, to be the most logical and practical scheme of urban drainage.

The sewer system of the City of Chicago consists of approximately 4,200 miles (6,720 km) of sewers with approximatly 360,000 appurtenances. These sewers serve a land area of 228 square miles (593 square kilometers) with a population, according to the 1980 Census, of 3,005,000 people.

The growth of population and increased urbanization resulted in the increase of impervious surfaces in the form of roofs, pavements and parking areas, causing greater runoff than had been allowed for in the original sewer designs. This created a situation where communities of Chicago, which were once considered to be adequately sewered, were subjected to basement and underpass flooding, even during minor storms.

In 1947, the City of Chicago launched a systematic program of designing and constructing large storm relief sewers. These were to be "combined" sewers with the dry-weather flow less than 5% of the total capacity, and since they were to supplement the existing major trunk sewers and not serve as substitutes, the name "Auxiliary Outlet Sewers" was coined.

Since 1947, more than 154 contracts have been awarded, and about 255 miles (408 km) of sewers, ranging in size from 24 inches (61 cm) to 21 ft. (6.4 m) in diameter, have been constructed at a cost of $234,000,000, financed under seven bond issues. An additional 31 miles (49.6 km) of new outlet sewers will be constructed in the next five years.

As continuation of this Auxiliary Outlet Sewer Program, the general area bounded by the North Branch of Chicago River, Irving Park Road, Oriole Avenue and Devon Avenue was selected in 1963 for relief from basement and underpass flooding (see Figure 2). Following a preliminary hydraulic study, a trunk sewer line was proposed in the vicinity of Wilson Avenue.

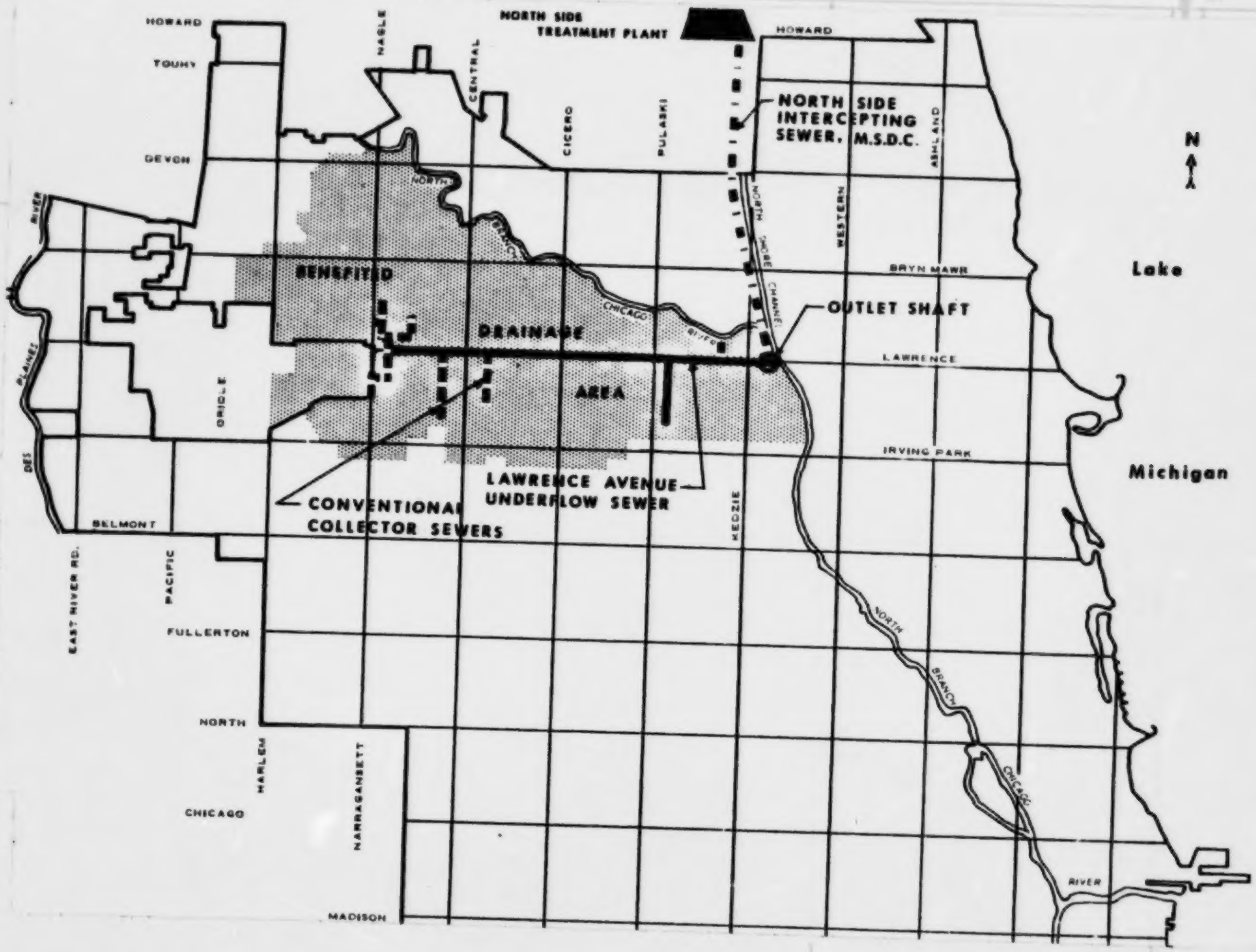
This proposal, termed as the Eastwood-Wilson Avenue Sewer System, called for a conventional high-level trunk sewer varying in size from a 2 barrel 13 ft. by 13 ft. (3.96m by 3.96m) section near the outfall, to 7.5 ft. (2.29m) diameter circular section at the upstream end. The construction was to be carried out by conventional methods of open cut excavation with a small portion under the expressways as earth tunnel. Figure 3 shows the plan and profile of the Eastwood-Wilson Sewer System.

As the significance of the combined sewer overflows in contributing pollution to the receiving waters became a prime concern of the engineers in this field, consideration was given to modifying the design with a view to reducing spillage of pollution to the waterway. Lowering the profile of the sewer system would provide storage and reduce the frequency of overflows. However, it would add to the costs by requiring pumping of the intercepted flows to the existing sanitary interceptor sewer. It would also require that more of the construction be performed by earth tunnel method, further adding to the costs.

Tunneling in underground rock strata 100 feet to 200 feet (30.5m to 61m) below surface level had previously been performed by the City of Chicago for construction of a number of water tunnels ranging in size from 12 feet to 16 feet (3.66m to 4.9m). These tunnels were constructed by the conventional drill and blast methods.

Development of rock mining machines (moles) used in large irrigation and hydroelectric projects throughout the world, had reduced tunneling costs. Preliminary cost analysis revealed that mined tunnels could be cost-competitive with conventional open-cut sewer. The tunnel option had the added advantage of little disruption of streets during construction, resulting in least inconvenience to residents, pedestrians, commercial enterprises, parking, vehicular traffic and interference with utilities, and also minimal atmospheric pollution and noise nuisance.

The City of Chicago, Department of Public Works, retained the services of the consulting engineers, Harza Engineering Company, to study the various alternative ways of providing the needed storm relief to the project area. After a comparative evaluation of the construction costs, the hydraulic per-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HARLEM
NARRAGANSETT
PACIFIC
EAST RIVER RD.
DES PLAINES RIVER
NORTH BRANCH CHICAGO RIVER
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Figure 2. Proposed Eastwood-Wilson Sewer System Location Map.

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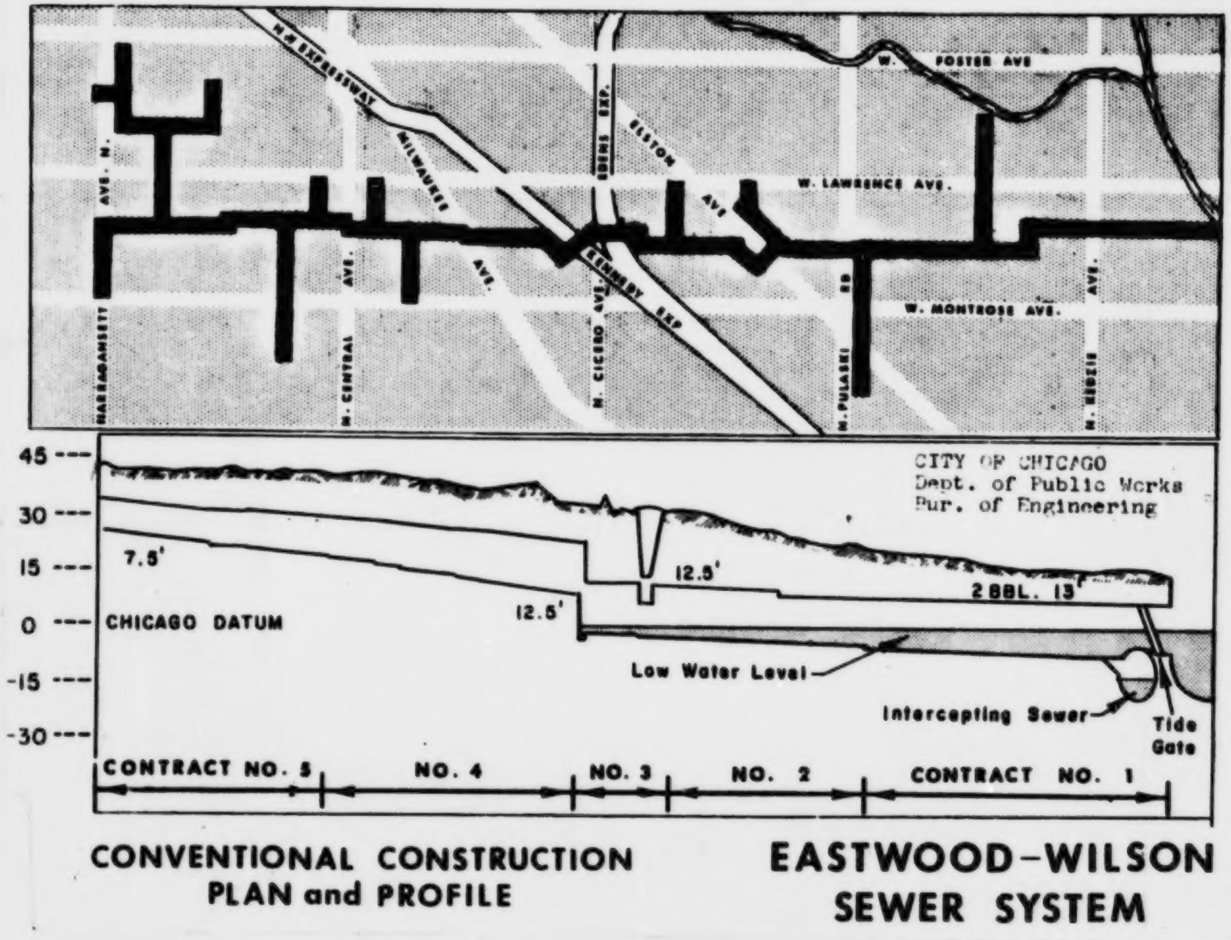
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PLAN and PROFILE
EASTWOOD-WILSON
SEWER SYSTEM

Figure 3. Plan and Profile of Proposed Eastwood-Wilson Sewer System.

formance and feasibility of the systems, and the operation and maintenance costs, it was decided to design a deep tunnel system with the main tunnel situated under Lawrence Avenue. Consequently, in November 1966 the project was redesignated as the "Lawrence Avenue Underflow Sewer System".

A rock boring program was carried out to a depth exceeding 250 feet (76m) for exploration of the underground strata along the proposed tunnel routes. After a careful analysis of the borings and the geologic characteristics of the underlying rock strata, the ease and cost of construction, the pumping costs, the pollutional effects on the adjacent aquifer, it was decided to build the tunnel at a depth ranging from 250 feet (76m) to 220 feet (67m) below the surface. Avoiding crossing too close to the Wilson Avenue Water Tunnel was also one of the considerations in selecting the tunnel profile.

C. PRINCIPAL FEATURES OF THE LAWRENCE AVENUE SEWER SYSTEM

The principal features of the Lawrence Avenue Underflow Sewer System are outlined in Figure 4. The main tunnel runs in the rock strata under Lawrence Avenue from the North Branch of Chicago River on the east, to Melvina Avenue on the west. A branch tunnel runs under Harding Avenue from Lawrence Avenue on the north to Berteau Avenue on the south.

The portion of the tunnel from the outfall to Kildare Avenue was originally designed as a 17 foot (5.20m) diameter concrete lined circular section with the remaining portion as a 12 foot (3.66m) diameter lined section. Also, the branch tunnel under Harding Avenue was designed as a lined 12 foot (3.66m) diameter section.

The contractor elected to use an existing rock mining machine that could be made available in a short time, but whose cutting face diameter was 13'-8" (4.17m). His procedure called for first mining the 17 foot (5.18m) tunnel with this machine at the correct bottom elevation, then enlarging to specified size by drill and blast methods. Because of this a substitute finished section was designed. Therefore the finished section is egg-shaped, 15'-6½" (4.74m) in width, and 19'-5" (5.9m) in height, instead of a 17 foot (5.2m) circular section as originally called for in the design.

Because of the excellent condition of the limestone in which the tunnel is located, it was decided to eliminate the concrete lining of the 12 foot (3.66m) sections which were

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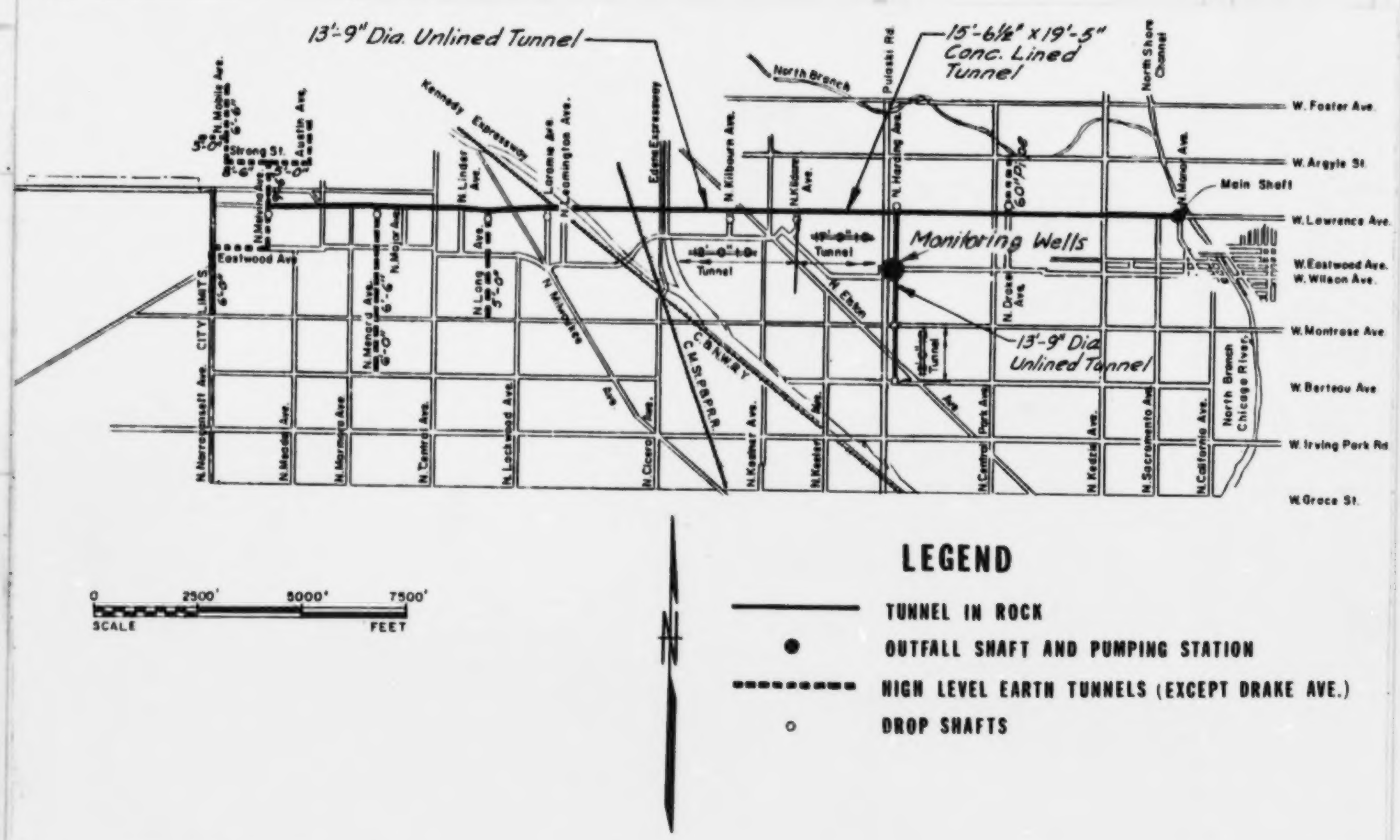
13'-9" Dia. Unlined Tunnel
15'-6½" x 19'-5" Conc. Lined Tunnel
13'-9" Dia Unlined Tunnel
Monitoring Wells
Main Shaft
60" Pipe
North Branch
North Shore Channel
North Branch Chicago River
Kennedy Expressway
Edens Expressway
C.&N.W.R.Y.
C.M.St.P.&P.R.R.
N. Milwaukee Ave
N. Elston Ave
Pulaski Rd.
CITY LIMITS
W. Foster Ave.
W. Argyle St.
W. Lawrence Ave.
W. Eastwood Ave.
W. Wilson Ave.
W. Montrose Ave
W. Berteau Ave
W. Irving Park Rd
W. Grace St.
N. Narragansett Ave.
N. Mobile Ave.
Strong St.
N. Melvina Ave.
Austin Ave.
Eastwood Ave
N. Menard Ave.
N. Major Ave.
N. Mango Ave.
N. Marmora Ave.
N. Central Ave.
N. Linder Ave.
N. Long Ave.
N. Lockwood Ave.
Laramie Ave.
N. Leamington Ave.
N. Cicero Ave.
N. Kilbourn Ave.
N. Keating Ave.
N. Kostner Ave.
N. Kildare Ave.
N. Kedvale Ave.
N. Harding Ave.
N. Drake Ave.
N. Central Park Ave.
N. Kedzie Ave.
N. Sacramento Ave
N. California Ave.
Tunnel
6'-0"
6'-6"
5'-0"
LEGEND
TUNNEL IN ROCK
OUTFALL SHAFT AND PUMPING STATION
HIGH LEVEL EARTH TUNNELS (EXCEPT DRAKE AVE.)
DROP SHAFTS
N
0
2500'
5000'
7500'
SCALE
FEET

Figure 4. Principal Features of Lawrence Avenue Sewer System

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machine-mined to a 13'-9" (4.19m) diameter. This resulted in a saving of $800,000 to the City, while adding 580,000 cubic feet (16,425 m3) to the storage capacity of the system. It was estimated that the enlarged unlined section would also provide the discharge capacity of the 12 foot (3.66m) lined section.

The high level sewers built as part of the Lawrence Avenue Sewer System are as follows:

1. A 60" (1.52m) diameter reinforced concrete pipe sewer along Drake Avenue northward from Lawrence Avenue to Argyle Street.
2. A 5'-0" (1.52m) diameter earth tunnel along Long Avenue southward from Lawrence Avenue to Montrose Avenue.
3. Along Menard Avenue southward, a 6'-6" (1.98m) diameter earth tunnel from Lawrence Avenue to Montrose Avenue, and a 6'-0" (1.83m) earth tunnel from Montrose Avenue to Berteau Avenue.
4. A 9'-6" (2.90m) diameter earth tunnel along Melvina Avenue northward from Lawrence Avenue to Gunnison Street and along Moody Avenue from Gunnison Street and along Moody Avenue from Gunnison Street to Strong Street.
5. A 5'-0" (1.52m) diameter earth tunnel along Strong Street eastward from Moody Avenue to Austin Avenue and along Austin Avenue northward from Strong Street to Higgins Avenue.
6. A 8'-6" (2.59m) diameter earth tunnel along Strong Street westward from Moody Avenue to Mobile Avenue and along Mobile Avenue northward from Strong Street to Argyle Street.
7. A 6'-6" (1.98m) diameter earth tunnel along Mobile Avenue northward from Argyle Street to Foster Avenue.
8. A 5'-0" (1.52m) diameter earth tunnel along Argyle Street westward from Mobile Avenue to Nagle Avenue.
9. A 6'-0" (1.83m) diameter earth tunnel along Melvina Avenue southward from Lawrence Avenue to Eastwood Avenue, along Eastwood Avenue westward from Melvina Avenue to Narragansett Avenue and along Narragansett southward from Eastwood Avenue to Montrose Avenue.

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Ten dropshafts were constructed to convey flows from high-level sewers to the rock tunnels. These are listed below:

	Location	Diameter
1.	Lawrence Avenue & Drake Avenue	7'-2" (2.19m)
2.	Lawrence Avenue & Harding Avenue	5'-8" (1.73m)
3.	Lawrence Avenue & Kildare Avenue	5'-8" (1.73m)
4.	Lawrence Avenue & Kilbourn Avenue	5'-8" (1.73m)
5.	Lawrence Avenue & Laramie Avenue	7'-2" (2.19m)
6.	Lawrence Avenue & Long Avenue	7'-2" (2.19m)
7.	Lawrence Avenue & Menard Avenue	7'-2" (2.19m)
8.	Lawrence Avenue & Melvina Avenue	9'-0" (2.74m)
9.	Harding Avenue & Montrose Avenue	5'-8" (1.73m)
10.	Harding Avenue & Berteau Avenue	9'-0" (2.74m)

The main shaft, 25'-0" (7.6m) in diameter, is located on the west bank of the North Branch of the Chicago River, slightly north of Lawrence Avenue. The flows through the tunnel rise up this shaft and discharge to the river through an outfall structure built adjacent to the shaft. The bottom of the shaft serves as a sump for the four (4) submersible pumps which are also housed at the bottom of the shaft, with their discharge pipes running vertically along the shaft walls to a vault structure from where the pumped discharge flows by gravity to the treatment plant.

Details of the various components of the Lawrence Avenue Sewer System, including planning and construction have been described in the Interim Report dated March 1980, Publication Number EPA-600/2-80-014.

D. SYNOPSIS OF THE INTERIM REPORT

The Interim Report is entitled "Lawrence Avenue Underflow Sewer System, Interim Report - Planning and Construction", and was published by the USEPA in March 1980 as Publication Number EPA-600/2-80-014.

The report traces the City of Chicago's history of sanitary engineering, storm drainage, tunneling for water supply and evolution of the system of combined sewers and describes the chronology of events leading to the development of the deep rock tunnel concept. The project need and background, conceptualization, planning, design and construction are covered in detail.

The evolution of the concept of deep rock tunnel to serve as a relief sewer and storage device in lieu of a conventional

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sewer system, has been described with the various considerations pointing in favor of the deep tunnel scheme. The system study with the help of a computer model, the underground exploration program, and various design considerations including geologic characteristics of rock strata, the ease and cost of construction, pumping aspects, aquifer pollution, etc., are dealt with in some detail.

The various contracts awarded for the construction of the project have been described in detail, including names of contractors, funding sources, award price, location and description of the specific work covered under the contract, starting and completion dates, construction methods, specifications of the mining machines and other equipment used, power and ventilation provisions, problems and difficulties encountered, contract modifications, and traffic and safety considerations. Photographs of construction in progress and some of the specialized equipment are included to facilitate a better understanding of the work involved in the project.

The hydraulic model studies conducted at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minnesota for the design of dropshaft structures, have been described briefly and a number of photographs of the models under a variety of flow and tailwater conditions are included in the report.

Finally, a brief outline of the Chicago Underflow Plan, later known as the Tunnel and Reservoir Plan (TARP), has been provided and its relationship to the Lawrence Avenue Underflow Sewer System has been explained.

E. SCOPE OF THE FINAL REPORT

The purpose of this study was to assess and demonstrate the effectiveness of the Lawrence Avenue Underflow Sewer System in reducing spillage of combined flows and pollutants to the North Branch of the Chicago River. In addition to "Conclusions" and "Recommendations" presented in Sections I and II, respectively, the scope of this report includes:

1. A brief description of the background of the project.
2. Description of the preproject monitoring of the flows and pollutants to the river and the treatment plant from selected outfalls in the Lawrence Avenue Sewer System drainage area.
3. Calibration of a computer program - the United States Environmental Protection Agency's Storm Water Management Model - With the data collected in Item 2 above.

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4. An evaluation of the system performance for a variety of storms utilizing the calibrated simulation model.
5. Description of the Groundwater Monitoring Program and an evaluation of the impact of the Lawrence Avenue Tunnels on the underground aquifer.
6. A documentation of the actual operating and maintenance experience with the Lawrence Avenue Underflow Sewer System.

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SECTION IV

PHASE I MONITORING - PREPROJECT CONDITIONS

A. DESCRIPTION OF STUDY AREA

The study area is shown in Figure 5, along with the major sewers and the outfalls. The area shown includes seven drainage basins, numbered 3 through 9, that are affected by the Lawrence Avenue Underflow Sewer System and two drainage basins, numbered 1 and 2, which contribute dry weather flow and a small quantity of intercepted combined flow during storms. A summary of the land use, population, area and imperviousness of the study area is included in Table 1. The total drainage area affected by the Lawrence Avenue System is 7,881 acres (3,192 hectares) as differentiated from the drainage area directly served by the Lawrence Avenue Underflow Sewer System, which is 3,583 acres (1,451 hectares).

Out of the seven conventional sewer outfalls affected by the Lawrence Avenue Tunnel System, those at Irving Park Road, Berteau Avenue, Montrose Avenue, Lawrence Avenue and Argyle Street are located on the North Branch of the Chicago River, south of its junction with the North Shore Channel. The remaining two outfalls, Foster Avenue and Forest Glen Avenue are located north of the junction. Miltimore Avenue and Imlay Street outfalls serve the two basins contributing intercepted flow only.

As is typical for the City of Chicago, the drainage area served by these outfalls are interconnected to each other. This is the reason the Lawrence Avenue Underflow Sewer System influences seven different drainage basins during storm periods. The land usage is 68.5 percent residential, 14.5 percent commercial, 1.1 percent industrial and 15.9 percent open land or parks. The total population is 191,157, or about 24 persons per acre (60 persons per hectare). The area is approximately 35 percent impervious. The length of the combined main trunks excluding the tunnel is approximately 22.1 miles (35.6km). The trunks branch into submains that are larger than 2 feet (0.61m) in diameter. The submains are fed by the laterals, 2 feet (0.61m) in diameter and smaller, running under each street. The dry weather flow (DWF), and during storm periods approximately twice that amount, for the areas served by the Imlay Street, Miltimore Avenue, Forest Glen Avenue, Foster Avenue and Argyle Street sewers passes respectively through these areas before finally being collected by the MSDGC Interceptor at Argyle Street near the North Branch of the Chicago River. Therefore, these areas have to be included in the calculation of the combined flows, even though the

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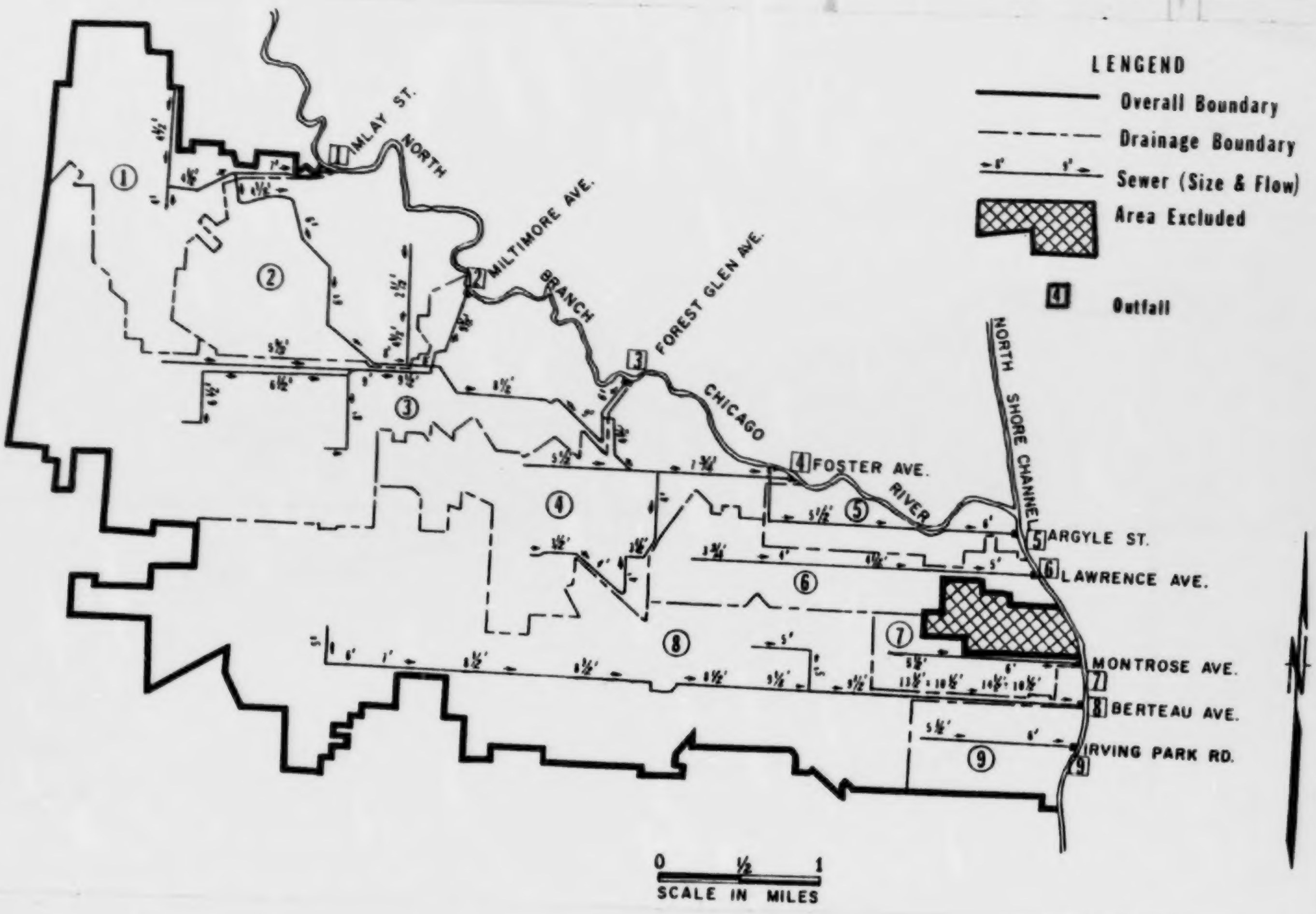
LENGEND
Overall Boundary
Drainage Boundary
Sewer (Size & Flow)
Area Excluded
4 Outfall
IMLAY ST.
NORTH
MILTIMORE AVE.
BRANCH
FOREST GLEN AVE.
CHICAGO
FOSTER AVE.
RIVER
NORTH SHORE CHANNEL
ARGYLE ST.
LAWRENCE AVE.
MONTROSE AVE.
BERTEAU AVE.
IRVING PARK RD.
①
②
③
④
⑤
⑥
⑦
⑧
⑨
1
2
3
4
5
6
7
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N
0
½
1
SCALE IN MILES

Figure 5. Study Area Drainage Boundaries and Principal Sewers-Preproject Conditions

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Table 1

Land Use, Population, and Imperviousness of Study Area - Preproject Condition

Drainage Basin	Land Use										Total Land Area Acres	Population Persons	Population Density Persons/Acre	Average Imperviousness %
	Single Family Residential		Multi-Family Residential		Commercial		Industrial		Open Land or Parks					
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%				
(1) Imlay St.	763	83.6	-	-	114	12.5	-	-	36	3.9	913	13,537	15	30
(2) MiltimoreAve.	699	65.1	-	-	152	14.1	-	-	223	20.8	1,074	13,442	13	33
(3) Forest Glen Ave.	1,786	78.1	-	-	255	11.2	-	-	245	10.7	2,286	45,388	20	32
(4) Foster Ave.	678	63.6	-	-	111	10.4	61	5.7	216	20.3	1,066	22,154	21	33
(5) Argyle St.	156	52.3	53	17.8	38	12.8	-	-	51	17.1	298	13,792	46	32
(6) Lawrence Ave.	319	57.1	62	11.1	136	24.3	-	-	42	7.5	559	16,141	29	45
(7) Montrose Ave.	290	79.7	-	-	49	13.4	-	-	25	6.9	364	18,250	50	42
(8) Berteau Ave.	1,783	61.1	-	-	507	17.4	19	0.6	611	20.9	2,920	60,577	21	35
(9) Irving Pk.Rd.	261	67.3	15	3.9	46	11.8	7	1.8	59	15.2	388	14,855	38	38
Total Area * (3) thru (9)	5,273	66.9	130	1.6	1,142	14.5	87	1.1	1,249	15.9	7,881	191,157	24	35

*Imlay St. and Miltimore Ave. basins are excluded as they are not affected by the Tunnel System.

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Imlay Street and Miltimore Avenue sewers primarily contribute dry weather flows to the affected area. The dry weather flow from Irving Park Road, Berteau Avenue, Montrose Avenue and Lawrence Avenue sewers is intercepted separately before each outfall. The system carries an average dry weather flow of 106 cfs (3.0 m3/sec). The intercepted flow is carried north to the North Side Sewage Treatment Works. The combined design capacity of the seven outfalls is 1,810 cfs (51.3 m3/sec). The Lawrence Avenue Tunnel has provided 1,500 cfs (42.5 m3/sec) of additional outlet capacity. The ground slopes downward toward the river at an average of about 1.0 foot per 1,000 feet (1.0m per 1000m).

B. OUTLINE OF APPROACH

The field monitoring of the seven outfalls described in the preceeding paragraphs for preproject and postproject conditions and of the Lawrence Avenue Tunnel outfall for postproject condition would require high costs of purchasing, installing and maintaining the equipment and facilities. Continued manpower requirements for carrying out the sampling program would also be in direct proportion to the number of sampling points. Moreover, the equipment installation would be an obstruction to flow which is undesirable, particularly considering the already prevalent basement flooding problems in the study area.

In view of the above considerations, it was decided to select three outfalls within the Lawrence Avenue drainage area for measuring the quantity and quality of the overflows being discharged to the North Branch of the Chicago River and the amounts intercepted and diverted to the treatment plant. The measured data would be collected manually during three to six separate storm periods of varying intensity and duration. The storms selected would be those which were anticipated to cause overflows to occur at the selected outfalls. The data collection crews would be alerted by weather forecasts to impending storms. They would be physically present at the sampling locations before the occurrence of overflows to take samples as well as measurements of parameters required for the calculation of discharge quantities at regular time intervals during the storm period.

The USEPA Storm Water Management Model is a sophisticated computer program capable of simulating the runoff and pollution from a combined sewer area such as the one under study. It had been used previously by the City of Chicago to aid in the design of the Tunnel and Reservoir Plan for the Chicagoland Area. Due to its availability and familiarity of City personnel with this model, it was ideal to use for this study.

This model would be calibrated with the preproject field data collected for the three outfalls. The drainage area data to be used would be processed from the data collected for the Chicago Underflow Plan by the City's consultants, Warren & Van Praag, Incorporated, as described in their report "Development of a Flood and Pollution Control Plan for the Chicagoland Area-Data Collection", Technical Report Part 1, December 1972. Because the study area is fully developed, the data is fully applicable without any modifications. The precipitation data needed for the computer simulation would be obtained from the continuous recording gages at Mayfair Pumping Station and the MSDGC's North Branch Pumping Station.

Since postproject monitoring was to continue at the Lawrence Avenue Tunnel outfall, and at least at one other outfall representative of the whole system in general, additional calibration runs were originally planned for the postproject conditions to ascertain whether the computer results corresponded to the measured data. However, due to the difficulties encountered in making the pumping station fully operational, this part of the calibration had to be forsaken in order to meet the deadline for completion of this report. Section V-A summarizes some of the problems faced in completion of the project.

With the model calibrated, overflow quantities and qualities would be computed for the seven outfalls affected by the Lawrence Avenue Tunnel for selected periods of analysis, for preproject conditions.

Computer runs would then be repeated for the same storms for the above seven outfalls and the Lawrence Avenue Underflow Tunnel for postproject conditions. The reduction in flows and pollution spilling to the waterway would then be determined by comparison.

C. SELECTION OF OUTFALL

Since the sampling program was to be carried out through manual operation, it was necessary that the sampling sites be conveniently located and easily accessible, particularly during adverse weather conditions. As much as possible, they should be representative of the general characteristics of the Lawrence Avenue System service area. The sampling process should cause minimum interference with traffic and be least liable to accidental hazards.

The measurements were to be taken for total flow and overflow, the difference of which would then give the flow intercepted. Thus, two sets of measurements were required for each outfall monitored, making a total of six sets of data.

The method used for velocity measurement required dropping floats at an upstream manhole and timing their appearance at a downstream manhole. Therefore it was necessary that four manholes or points of access be available along each sewer in the vicinity of the sampling site. Two of these had to be upstream from the diversion structure, and the other two to be somewhere between the diversion structure and the outfall. It was also necessary that the outfall be close to the diversion structure with no or minimal local inflow. Since a grab sample was to be taken from the river, the accessibility of the river for sampling was also a consideration in the selection of the outfalls. The outfalls along the North Branch of the Chicago River upstream from the junction with the North Shore Channel, namely, Forest Glen Avenue and Foster Avenue, are relatively difficult to reach. Their intercepting structures are quite far upstream from the outfalls. During storms, the combined flow through these outfalls includes dry weather flow from a much larger upstream area outside the tributary storm runoff area making these less desirable to use as representative outfalls. Moreover, the intercepted flow from these areas eventually goes to the Argyle Street sewer where it is finally diverted to the MSDGC Interceptor near the Argyle Street outfall.

The Argyle Street outfall is very close to the intercepting structure with no access to the sewer for measurement of overflow to the river.

The Berteau Avenue sewer is a large 14½ feet x 10½ feet (4.42m x 3.20m) size section serving a relatively large drainage area. The outfall is partially submerged as the invert is several feet below the normal water level in the river at that location. This makes it difficult to measure flows accurately. Also, the quality of samples would be susceptible to errors.

In view of the aforementioned considerations, the remaining outfalls located along Lawrence Avenue, Montrose Avenue and Irving Park Road were selected for data collection. The Lawrence Avenue conventional high level sewer outfall serves the central core of the much larger service area of the Lawrence Avenue Underflow Sewer System. Therefore, the Lawrence Avenue outfall fairly represents the characteristics of the study area in general. The selected three outfalls are relatively less influenced by the cross connections in the sewer system.

Figures 6, 7 and 8 show the location and sampling points for the Lawrence Avenue, Montrose Avenue and Irving Park Road outfalls respectively. Water level is measured and floats are dropped into the flow stream at points A and C. The floats are timed and samples taken at points B and D. Points A, B measure total flow, and points C, D measure overflow to the river.

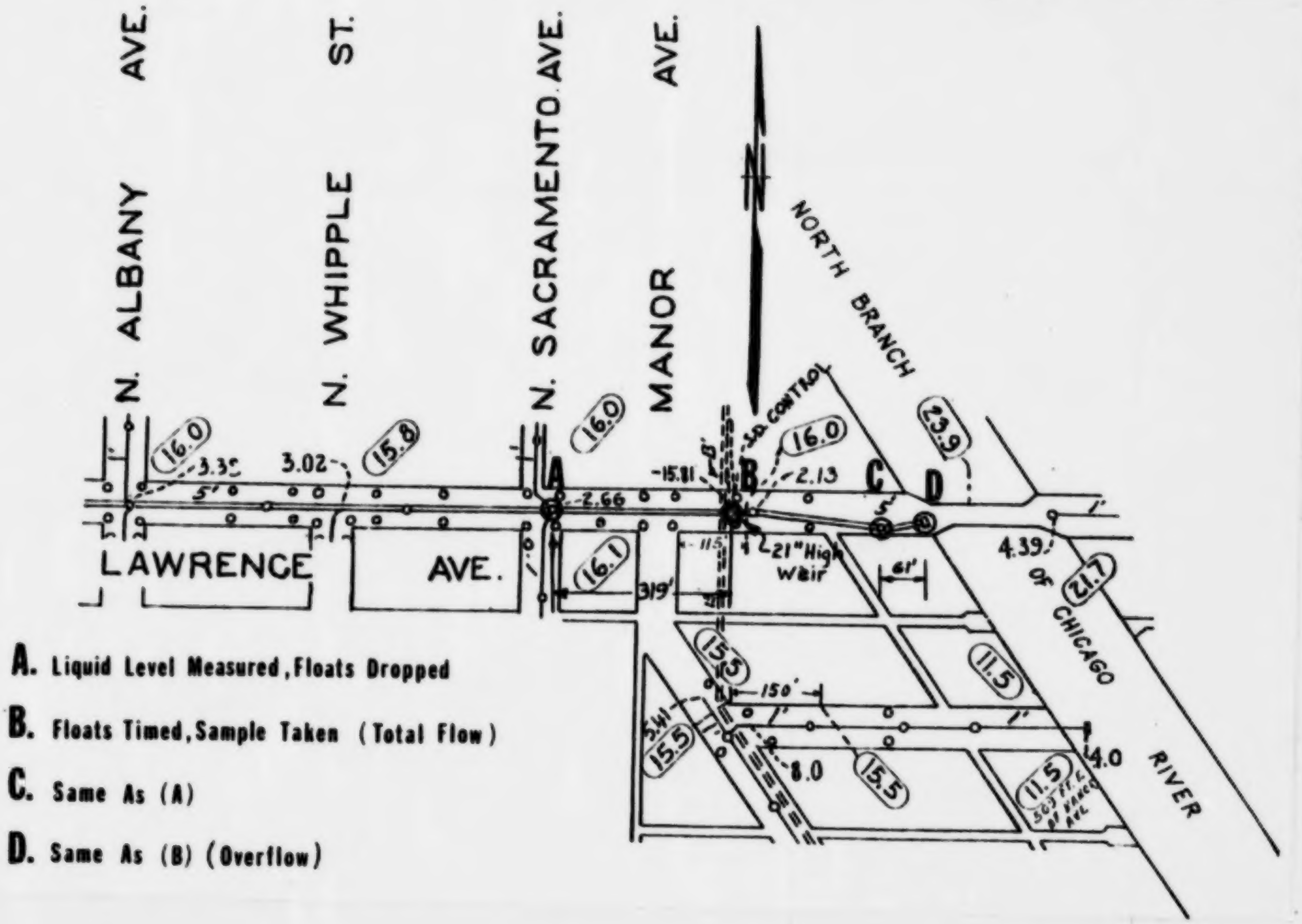
For the 5 foot (1.52m) diameter Lawrence Avenue sewer, the manhole at Sacramento Avenue is used as point A. Slightly downstream from Manor Avenue is the MSDGC intercepting structure with a 21-inch (0.53m) high weir across the flow direction. The manhole just upstream from the weir is used as point B, located at a distance of 319 feet (97m) from point A. The manhole immediately downstream from the intercepting structure is point C, located 61 feet (18.6m) upstream from the outfall which is used as point D.

For the 6 foot (1.83m) diameter Montrose Avenue sewer, the manholes at Mozart Street and California Avenue are used as points A and B respectively. The intercepting structure with a 28-inch (0.71m) high weir is located downstream of California Avenue. Point C is the manhole at Fairfield Avenue and point D is the outfall. The distance between points A and B is 332 feet (101 m) and between C and D is 584 feet (178 m). There is another weir, 21 inches (0.53m) high, located near the outfall to intercept inflows between California Avenue and the outfall.

For the 6 foot (1.83m) diameter Irving Park Road sewer, the points A and B are at the manholes on Mozart Street and California Avenue respectively. The intercepting structure is downstream of California Avenue with a 30-inch (0.76m) weir across the sewer. The distance between points A and B is 331 feet (101 m). The two manholes between California Avenue and the outfall are used as points C and D respectively with a distance of 339 feet (103 m) between them.

D. DATA COLLECTION

As stated earlier, it was decided that the data collection program would be conducted manually by sending crews to the sampling locations at the time of each storm to be monitored. There appeared two alternative choices available:
1) Use of City personnel from the Department of Sewers, then called Bureau of Sewers; or 2) Retain private consultants. It was anticipated the field crew personnel may be required to


N. ALBANY AVE.
N. WHIPPLE ST.
N. SACRAMENTO AVE.
MANOR AVE.
LAWRENCE AVE.
NORTH BRANCH OF CHICAGO RIVER
N
S.D. CONTROL
21" High Weir
16.0
3.39
3.02
15.8
16.0
2.66
-15.81
16.0
2.13
23.9
21.7
4.39
16.1
319'
115
61'
15.5
150'
15.5
3.41
8.0
15.5
11.5
11.5
4.0
A
B
C
D

A. Liquid Level Measured, Floats Dropped

B. Floats Timed, Sample Taken (Total Flow)

C. Same As (A)

D. Same As (B) (Overflow)

Figure 6. Sampling Location for Lawrence Avenue Outfall.

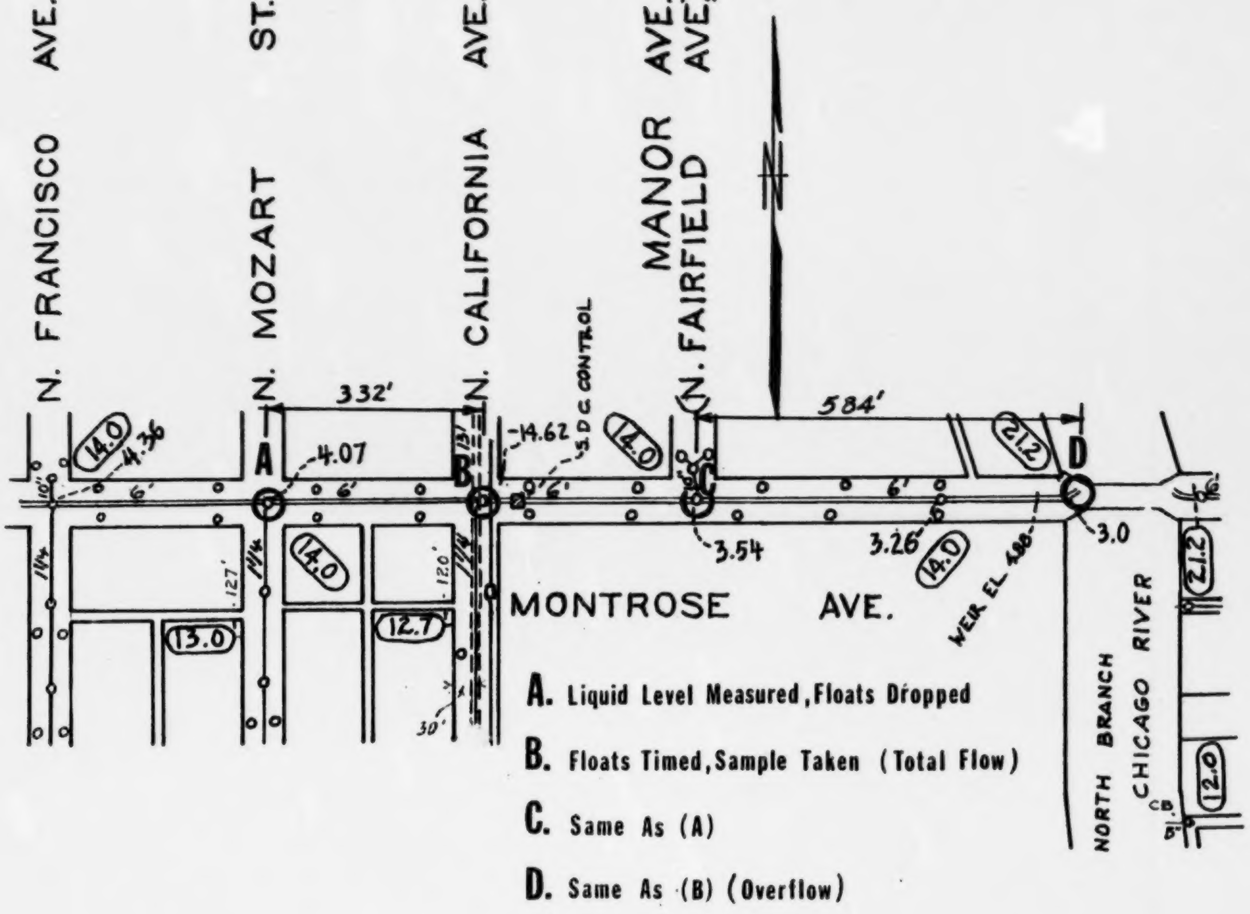

N. FRANCISCO AVE.
N. MOZART ST.
N. CALIFORNIA AVE.
MANOR AVE.
(N. FAIRFIELD AVE.)
MONTROSE AVE.
NORTH BRANCH CHICAGO RIVER
332'
584'
A
B
C
D
4.36
4.07
14.62
S.D.C. CONTROL
3.54
3.26
3.0
WEIR EL 4.80
14.0
14.0
14.0
14.0
13.0
12.7
21.2
21.2
12.0
6'
10'
127'
120'
30'
CB
A. Liquid Level Measured, Floats Dropped
B. Floats Timed, Sample Taken (Total Flow)
C. Same As (A)
D. Same As (B) (Overflow)

Figure 7. Sampling Location for Montrose Avenue Outfall.

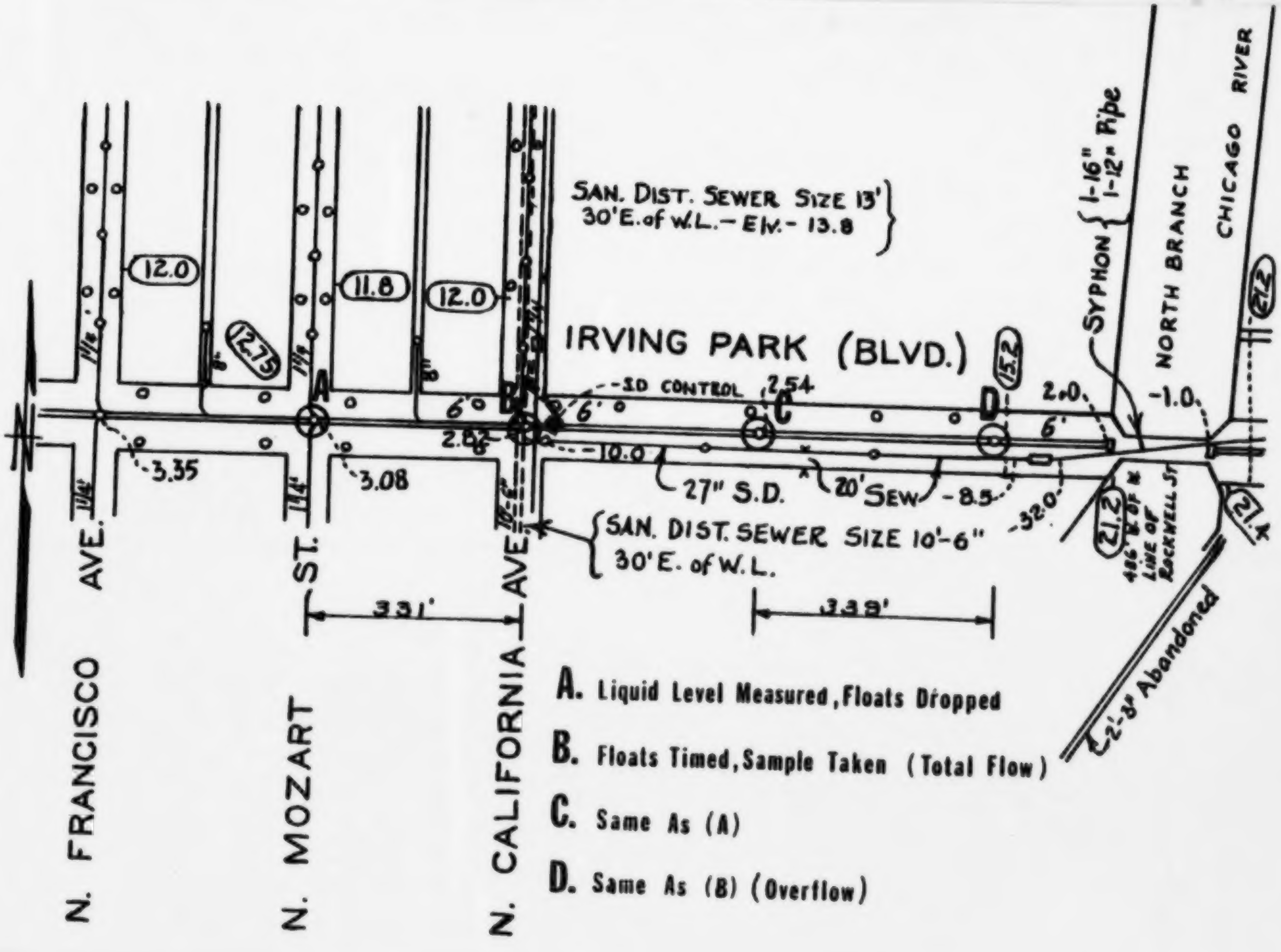

SAN. DIST. SEWER SIZE 13'
30'E. of W.L. - Elv. - 13.8
IRVING PARK (BLVD.)
SYPHON 1-16" 1-12" Pipe
NORTH BRANCH
CHICAGO RIVER
21.2
21.2
21.4
15.2
12.0
11.8
12.0
12.75
-SD CONTROL
2.54
2.0
-1.0
6'
6'
6'
2.82
-10.0
27" S.D.
20' SEW
-8.5
-32.0
3.35
3.08
486' E. of W. LINE OF ROCKWELL ST
2'-3" Abandoned
SAN. DIST. SEWER SIZE 10'-6"
30'E. of W.L.
331'
339'
A
B
C
D
N. FRANCISCO AVE.
N. MOZART ST.
N. CALIFORNIA AVE.
A. Liquid Level Measured, Floats Dropped
B. Floats Timed, Sample Taken (Total Flow)
C. Same As (A)
D. Same As (B) (Overflow)

Figure 8. Sampling Location for Irving Park (Blvd.) Road Outfall.

work during outside normal working hours also. It was also imperative that a dependable program be conducted because data lost, when samples are not taken properly, is not replaceable. The consulting engineering firm of Consoer, Townsend and Associates had earlier carried out a similar demonstration project for the City of Milwaukee. The City therefore decided to retain the services of this consulting firm for the data collection program.

In regard to the chemical and bacteriological analyses of the samples collected, again there were two alternative options, use of a private laboratory or obtaining assistance from the City's Bureau of Water, now called the Department of Water. It was found feasible and economical to conduct the testing "in-house" in the laboratory of the City's Central Water Filtration Plant. The Filtration Plant Laboratory agreed to provide the necessary sampling bottles for the crews, store the samples and conduct the necessary tests.

The Metropolitan Sanitary District's Maintenance and Operation Division continuously monitors U.S. Weather Bureau information with regard to anticipated storms. They agreed to include the City's project manager in the notification list for impending storms. They were requested to inform the City project manager of any anticipated storms expected to exceed 0.4 inch (1 cm) in depth. It was estimated that rainfall quantity of this magnitude would cause overflows to occur at the three selected outfalls.

The scope of the consultants services required gathering of test data during six separate storm periods of varying intensity and duration, while the respective sewer conduits would overflow to the North Branch of the Chicago River. It called for taking measurements of velocities, depths of flows and samples for the six selected test sites at every 15 minutes for the first two hours of a storm and during peak flow, and every hour thereafter for longer duration storms.

The monitoring crews would respond to notification of impending storm and overflow conditions on Monday through Friday, to monitor storms which would occur during the daylight hours. Monitoring personnel would work into the evening hours on storm incidents started prior to the normal Engineer's office closing time of 4:45 P.M. It was the understanding that notification of pending storms may be directed to the Engineers earlier than the normal office opening hour of 8:00 A.M. and the total number of hours a crew may be involved in a given storm event would not normally exceed 10 hours, including mobilization and demobilization.

The total number of unsuccessful events, that is, storms for which mobilization is accomplished but no overflow occurs, were estimated as not to exceed three (3) incidents for Phase I of the program. However, the unsuccessful events far exceeded this estimate, as described later.

As all the testing sites were along busy arterial streets, it was necessary to close one lane of traffic at each location, for which the necessary arrangements were made with the City's Department of Streets and Sanitation.

A total field crew of twenty (20) people were required to staff the monitoring program. This crew size included seven (7) people who would function as flagmen for traffic control.

The Consultants furnished all raingear, flags, signals, warning lights, barricades or other safety equipment which are considered reasonable and necessary in the circumstances to minimize the possibility of injury or damage to personnel or property during the monitoring activities.

Before actually embarking upon the monitoring program, an office meeting, a field visit and a field training session were conducted to prepare the crews for the sampling operation.

When the City personnel received notification from the MSD dispatcher, the information was passed on to the consultants who had agreed to mobilize their crews at a two-hour notice.

On arrival at the site and before the storm, the crew took a sample of the intercepted flow and a grab sample of the river water. Immediately after the storm sampling series, the crew took another grab sample of the river water. All sample bottles were labeled as to date, time, location, and total flow or overflow. The test samples were properly refrigerated and delivered as soon as possible to the Central Water Filtration Plant for analysis. A fresh supply of sample bottles was obtained from the Filtration Plant in preparation for the next storm.

Half gallon or 5-pint regency bottles (1.9 Liters) were used for chemical analysis, and 8-ounce (227 gm) sterilized bottles were used for bacteriological tests.

The following tests were performed in the Laboratory, using Standard Methods of testing:

Biochemical Oxygen Demand (mg/1)

Chemical Oxygen Demand (mg/1)

Suspended Solids (mg/l)
Settleable Solids (mg/l)
Ammonia Nitrogen (mg/l)
Organic Nitrogen (mg/l)
Total Coliforms (MPN/100 ml)

As the program went into operation, it was learned that most of the times the storms did not turn out to be as predicted by weather forecasting. The storm conditions causing overflows had been infrequent, and most of the events occurred either during night time hours or on weekends. As stated earlier, our agreement with the Consultants required them to respond to potential storm conditions essentially only during day time hours on week days. As a consequence, even after three months of effort, data could be obtained only for one storm with partial overflow during that event.

The City therefore requested the Consultants to alter their operation so that they would then also respond to night time calls advising them of imminent storms. This required that they place the entire crew of monitoring personnel on standby for specified night and even Saturday operations. Additional payments had to be made for keeping personnel on standby during non-working hours, adding to the cost of overall operation. To keep the City project manager accessible to the MSDGC dispatchers at all times, particularly when he might be on field assignments, arrangement was made with the Sanitary District for use of one of their page units and charger by the City project manager.

In light of the experience gained with the initial attempts for sampling, the MSDGC was requested to change the notification of a storm from greater than 0.4 of an inch (1.0 cm) of rain to a storm of greater than 0.2 of an inch (0.5 cm).

The following paragraphs summarize the data collection effort for the Phase I monitoring, extending over a 16-month period from August of 1974 to November of 1975.

1. Preliminary Work

In August, 1974 an office instructional meeting, a field training session, and field survey were conducted to prepare the crews for impending storms.

2. Standby

On five occasions during the subject sampling period the crews were alerted during non-working hours of impending storms, but were not sent out because conditions changed.

3. Unsuccessful Events

During the period of June through September 1975, sampling crews were sent out on six (6) unsuccessful occasions. Rainfall did take place but no overflows occurred at the sampled outfalls.

4. Partially Successful Events

On April 23, 1975 a partially successful event was conducted. The Lawrence Avenue Sewer was already overflowing when the crew reached the sampling area. Montrose and Irving Park Sewers did not overflow during the storm. On June 17, 1975 another partially successful event was conducted. The Lawrence Avenue Sewer overflowed during the storm, but Montrose and Irving Park Sewers did not overflow. Another partially successful event was conducted on November 9th and 10th, 1975. Sufficient manpower was not available to monitor all three sewers because the crews were not on standby. Samples and flow measurements were obtained from the Montrose Avenue and Irving Park Road sewers during that event.

5. Successful Events

The first field trip which was completely successful occurred on July 23, 1975 when all three sewers overflowed. The sewers at Lawrence Avenue and Irving Park Road were already overflowing when the crews arrived.

During the month of August 1975 successful events were conducted on August 1st and 11th. In the storm of August 11th, the sewers at all three sampling points were overflowing when the crews arrived. Following the storm of August 11th, the next successful event occurred on October 24, 1975.

6. Other

Dry weather flow measurements were performed at Lawrence Avenue, Montrose Avenue and Irving Park Road sewers on October 28, 1975.

Figure 9 shows the locations of the continuous recording rain gages in the study area and the Thiessen's polygon line

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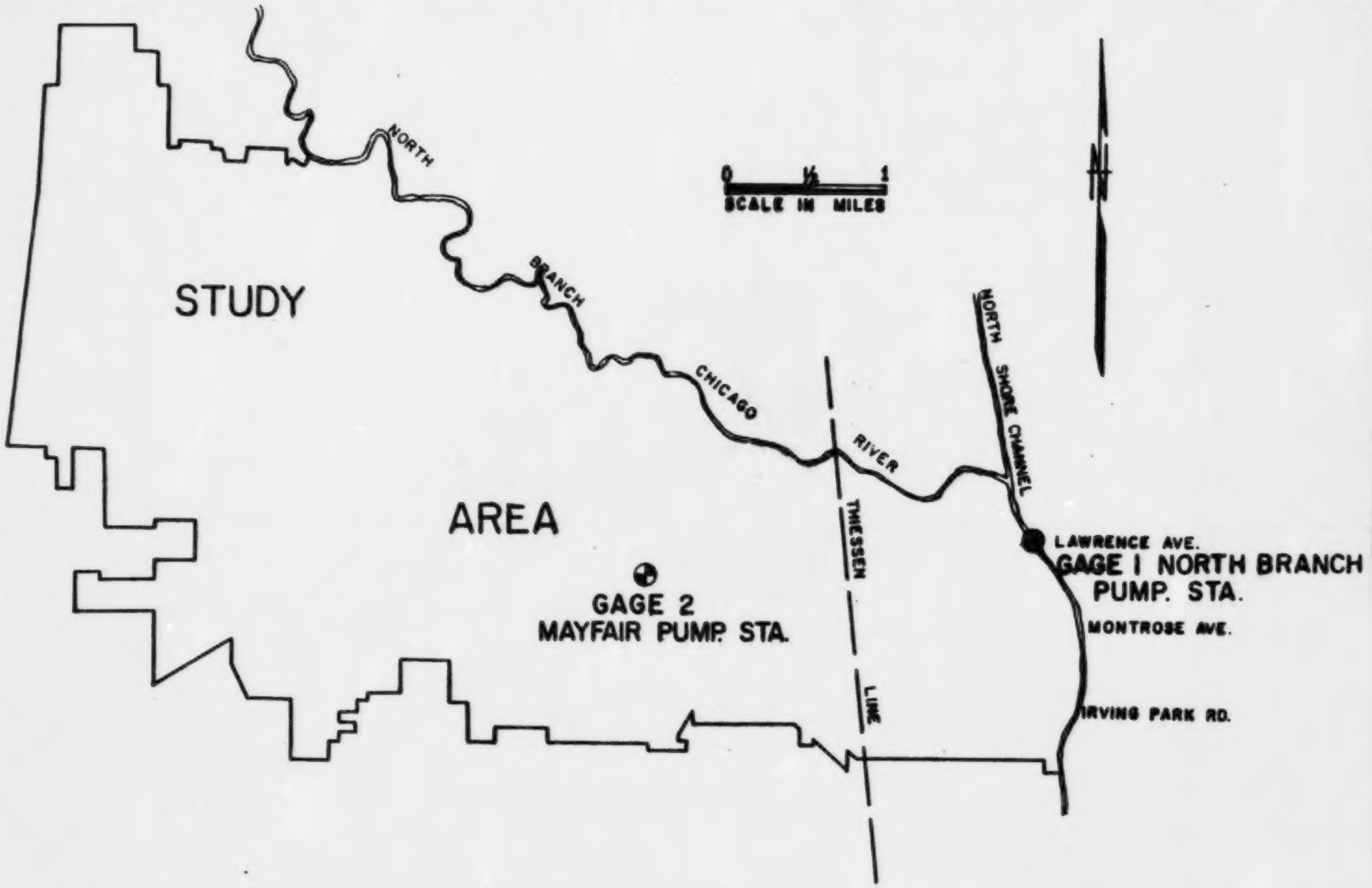
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AREA
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BRANCH
CHICAGO
RIVER
NORTH SHORE CHANNEL
THIESSEN
LINE
LAWRENCE AVE.
GAGE I NORTH BRANCH
PUMP. STA.
MONTROSE AVE.
IRVING PARK RD.
GAGE 2
MAYFAIR PUMP. STA.

Figure 9. Rain Gage Locations for Study Area.

for the gages. The North Branch Pumping Station rain gage is located on the east bank of the North Branch of the Chicago River, just north of Lawrence Avenue. It is operated by the Metropolitan Sanitary District, which supplied the recording charts for the desired storms. The only other rain gage applicable to the study area is located at the City's Mayfair Pumping Station along Wilson Avenue near Cicero Avenue. The Department of Water, City of Chicago, operates this gage and they furnished the recording charts for the desired precipitation data.

When the flows are small, the percent error in measurement and therefore in computer simulation, is higher, making the calibration of the model less reliable. Therefore it is desirable to have some flow measurements for storms that cause the monitored sewers to run at or near capacity. With this in view, intensive attempts were made for fifteen months to capture some heavy rain storms. However, due to the inaccuracy of weather predicting, the data collected by the end of November, 1975 was limited to storms with a total rainfall of between 0.39 inches (1 cm) and 1.18 inches (3 cm). Two of the outfalls, while having substantial overflows, did not discharge at peak capacity during the testing period. However, in view of the effort already applied and the onset of winter, it was decided to proceed on the basis that further preproject testing would be discontinued, and the computer model would be calibrated with the data already gathered.

E. DATA PROCESSING

A sample of the note sheets used for recording field observations is reproduced in Tables 2 and 3. The sheets include information on the name of persons taking observations, location, date of data collection, time of arrival to the site, start of overflow to the river, whether the flow is non-surcharged or surcharged, time of observation, distance from the manhole frame to the water level, time interval for float travel, indication if a sample was taken and whether the sample was from overflows or the river.

Tables 4 and 5 show respectively the samples of the chemical analysis and the bacteriological analysis reports received from the laboratory. Originally a test for the Dissolved Oxygen (D.O.) was considered desirable. However, as the samples were not analyzed immediately after collection, the results would be inaccurate, as the D.O. changes with time. The test was therefore not carried out.

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Table 2

Sample Field Notes

DATA SHEET

SHEET NO. 1
OF 1 SHEETS

Chicago Flow Monitoring--74216

NAME: - KILBURN

LOCATION:[5] MONTROSE - PT. C

DATE: 10/24/75

TIME OF ARRIVAL: 2:00 PM

START OF OVERFLOW: 4:45 PM

NOTES:

CONDITION[1]	Time Of Measurement TIME OF DAY	FLOAT TIME[2]	Ft. DISTANCE TO[3] WATER LEVEL	NOTES[4]
N	4:45		7.80	
N	5:00		800	
N	5:15		8.20	
N	5:30		8.50	
N	5:45		8.65	
N	6:00		8.95	
start of				
overflow	8:15		7.95	
N	9.00		7.60	
N	9:15		7.65	
N	9:30		7.75	
N	10:30		8.75	

Enter "N" or "S" in this column to indicate Non-Surcharged or Surcharged flow.
Entries shall be made in this column at point B and D during Non-Surcharged flow.
Entries shall be made in this column at point A and C always and at point B during Surcharg flow.
Check mark "✓" under Note denotes sample taken.
For Location, indicate Street and Position--i.e., "Lawrence Ave. -Point A".

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Table 3

Sample Field Notes

DATA SHEET

SHEET NO. 1
OF 1 SHEETS

Chicago Flow Monitoring--74216

NAME: LOUIS CHUCKA AND JIM KEATING
LOCATION:[5] MONTROSE - D
DATE: 10-24-75
TIME OF ARRIVAL: 2:00 PM
START OF OVERFLOW: 4:45 PM
NOTES:

CONDITION[1]	SAMPLE TIME OF DAY	STOP WATCH INTERVAL FLOAT TIME[2]	DISTANCE TO[3] WATER LEVEL	NOTES[4]
	2:20			R✓
	4:58	12 MIN 12 SEC		O✓
	5:07	6 MIN 29 SEC		O✓
	5:21	5 MIN 11 SEC		O✓
	5:35	3 MIN 47 SEC		O✓
	6:00	14 MIN 3 SEC		O✓
	6:07	END OF O	VERFLOW	
	6:10			R✓
	8:15	START OF	OVERFLOW	
	8:20	3 MIN 52 SEC		O✓
	9:04	2 MIN 46 SEC		O✓
	9:27	10 MIN 54 SEC		O✓
	9:44	13 MIN 38 SEC		O✓
	10:45	END OF	OVERFLOW	
	10:50			R✓

Enter "N" or "S" in this column to indicate Non-Surcharged or Surcharged flow.
Entries shall be made in this column at point B and D during Non-Surcharged flow.
Entries shall be made in this column at point A and C always and at point B during Surcharged flow.
Check mark "✓" under Note denotes sample taken.
For Location, indicate Street and Position--i. e., "Lawrence Ave. -Point A".

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Table 4

Sample Chemistry Laboratory Report

CITY OF CHICAGO DEPARTMENT OF WATER & SEWERS
WATER PURIFICATION DIVISION WATER PURIFICATION LABORATORY
CHEMISTRY UNIT

Date 11-7-75

Date Collected 10-24 & 25-75
Sample Source Sewers & Chicago River
Collected By Consoer Townsend & Associates
Location See Below
Date Rec'd in Lab. 10-27-75
Submitted By Dept. of Public Works

CHICAGO FLOW MONITORING Analysis Report

LOCATION	TIME	*SETT. SOLIDS	SUSP. SOLIDS	D.O.-°C	** BOD	COD	NH_3-N	ORG.N
Montrose Ave. Overflow	4:58 P	1.5	316		90.4	85.0	1.60	6.40
" " "	5:07 P	8.0	614		233	86.7	1.20	6.40
" " "	5:21 P	6.0	702	N	243	85.0	1.00	6.40
" " "	5:35 P	4.5	485		143	85.0	1.00	6.40
" " "	6:00 P	0.8	169	O	59.1	69.7	1.40	3.60
" " "	8:20 P	2.0	303	T	1162	79.9	0.70	4.00
" " "	9:04 P	0.3	86		10.3	42.5	0.80	3.60
" " "	9:27 P	0.5	84		7.0	37.4	0.70	2.40
" " "	9:44 P	1.0	48	D	20.9	34.0	2.70	2.00
Montrose Ave. River	2:20 P	<0.1	12		13.9	22.1	1.10	2.40
" " "	6:10 P	1.0	25	O	122	83.3	1.10	4.00
" " "	10:50 P	0.1	61	N	24.3	57.8	5.20	2.40
Irving Park Total	Initial	<0.1	24	E	48.7	74.8	2.90	6.40
" " "	4:30 P	2.5	417		539	85.0	0.90	6.40
" " "	4:45 P	4.5	495		223	83.3	1.70	6.40

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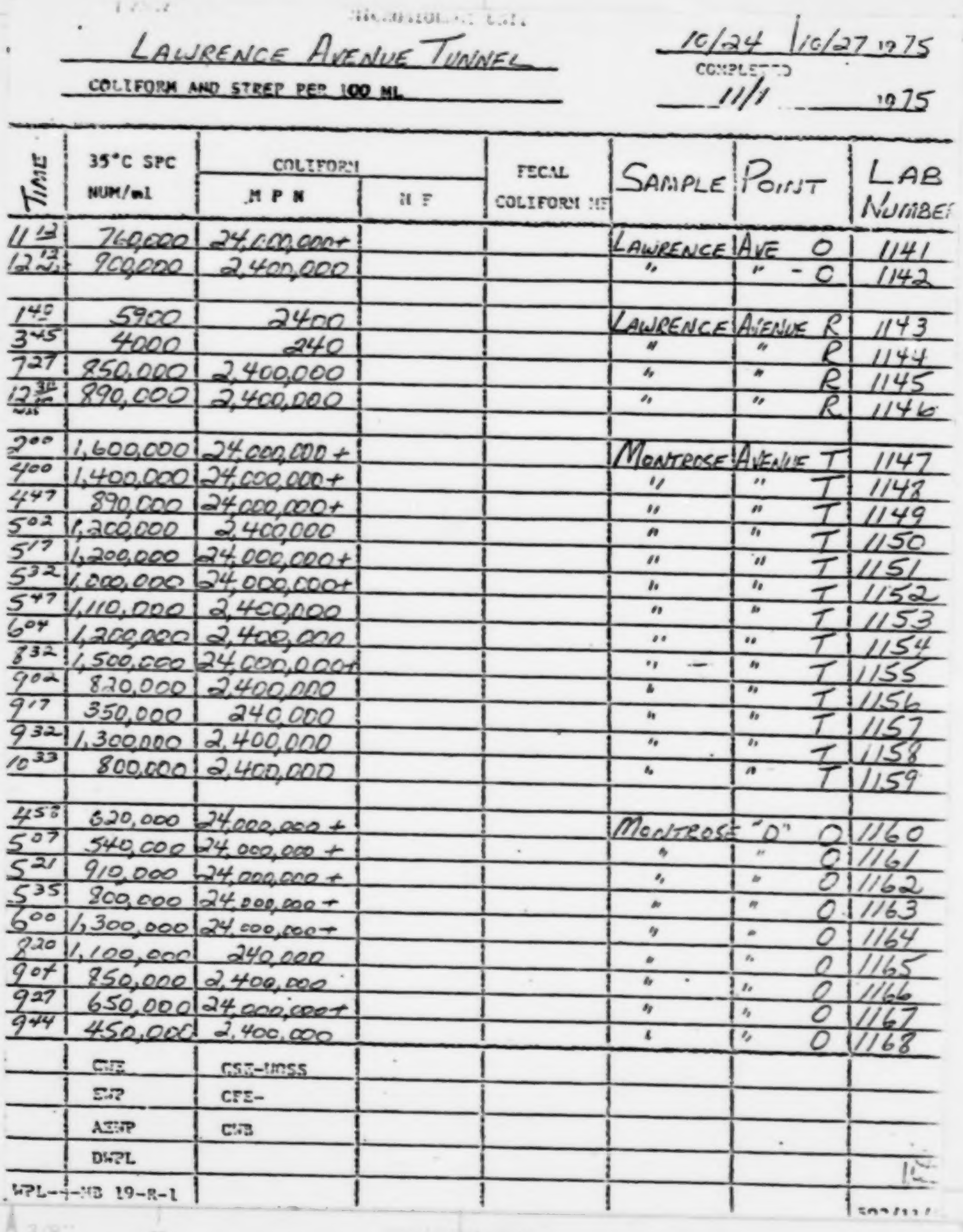
Table 5

Sample Microbiology Laboratory Report



LAWRENCE AVENUE TUNNEL

COLIFORM AND STREP PER 100 ML

10/24 | 10/27 1975

COMPLETED

11/1 1975

TIME	35°C SPC NUM/ml	COLIFORM		FECAL COLIFORM MF	SAMPLE	POINT	LAB NUMBER
		M P N	M F				
11^{13}	760,000	24,000,000+			LAWRENCE	AVE O	1141
12^{13}	900,000	2,400,000			"	" - O	1142
1^{40}	5900	2400			LAWRENCE	AVENUE R	1143
3^{45}	4000	240			"	" R	1144
7^{27}	850,000	2,400,000			"	" R	1145
12^{30}	890,000	2,400,000			"	" R	1146
2^{00}	1,600,000	24,000,000 +			MONTROSE	AVENUE T	1147
4^{00}	1,400,000	24,000,000+			"	" T	1148
4^{47}	890,000	24,000,000+			"	" T	1149
5^{02}	1,200,000	2,400,000			"	" T	1150
5^{17}	1,200,000	24,000,000+			"	" T	1151
5^{32}	1,000,000	24,000,000+			"	" T	1152
5^{47}	1,110,000	2,400,000			"	" T	1153
6^{04}	1,200,000	2,400,000			"	" T	1154
8^{32}	1,500,000	24,000,000+			" —	" T	1155
9^{02}	820,000	2,400,000			"	" T	1156
9^{17}	350,000	240,000			"	" T	1157
9^{32}	1,300,000	2,400,000			"	" T	1158
10^{33}	800,000	2,400,000			"	" T	1159
4^{58}	620,000	24,000,000 +			MONTROSE	"D" O	1160
5^{07}	540,000	24,000,000 +			"	" O	1161
5^{21}	910,000	24,000,000 +			"	" O	1162
5^{35}	800,000	24,000,000 +			"	" O	1163
6^{00}	1,300,000	24,000,000+			"	" O	1164
8^{20}	1,100,000	240,000			"	" O	1165
9^{04}	850,000	2,400,000			"	" O	1166
9^{27}	650,000	24,000,000+			"	" O	1167
9^{44}	450,000	2,400,000			"	" O	1168
	CWE	CSE-UDSS					
	EWP	CFE-					
	AEWP	CWB					
	DWPL						

WPL--HB 19-R-1

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The measurements taken for computation of flow quantities and the laboratory analysis reports from the Filtration Plant were then used by the consultants to carry out the necessary computations and tabulate the discharge quantities and pollutional loads for the storms monitored. A sample of the flow computations is shown in Table 6.

The title of the table gives the sampling location, date, and diameter of the sewer. The columns are as follows:

Column 1 - Time of measurement
Column 2 - Stop watch interval giving time of travel of the floats between two manholes.
Column 3 - Distance travelled by floats.
Column 4 - Surface velocity which is computed by dividing Column 3 with Column 2.
Column 5 - Average velocity which was obtained by multiplying Column 4 with a factor of 0.85.
Column 6 - Distance from manhole top to the water surface.
Column 7 - Distance from manhole top to the sewer invert.
Column 8 - Depth of flow which is the difference between Columns 7 and 6.
Column 9 - Ratio of depth of flow to sewer diameter.
Column 10- Cross sectional area of flow, obtained from hydraulic characteristics of circular sewers.
Column 11- Rate of discharge in cubic feet per second, obtained by multiplying Column 5 with Column 10.

Table 7 shows a sample of the computations for pollutants in the measured flows. Location, date of sampling and name of pollutant are marked on the top of the table. The example is for the Suspended Solids. Similar computations are tabulated for other pollutants also. The columns are as follows:

Column 1 - Time of measurement.
Column 2 - Rate of discharge (CFS), obtained from Table 6.
Column 3 - Pollutant concentration from laboratory analysis in mg/1.
Column 4 - Average discharge during interval.
Column 5 - Time interval during consecutive measurements.
Column 6 - Weighted average concentration of pollutant during the interval.
Column 7 - Pollutant loading in pounds per day.
Column 8 - Pounds of pollutant discharged during time interval.
Column 9 - Time and concentration of grab samples from upstream of intercepting structure and river.

Table 6

Sample Computation Of Flow Rate

POINT A-B D=6 FT 10-24-75 MONTROSE

TIME OF MST HR MIN	STOP WCH INTERVAL MIN SEC	MH DIST FT	SURF VEL FT/SEC	AVE VEL FT/SEC	DIST TO LIQ LVL E(FT)	DIST TO INVERT F(FT)	G(FT) F-E=G	H G/D	AREA SQ.FT	Q CFS
4-45	1-36.0	332	3.458	2.939	6.700	9.980	3.290	0.546	15.814	46.488
5- 0	1-43.0	332	3.223	2.739	7.070	9.980	2.910	0.485	13.577	37.253
5-15	2- 1.0	332	2.743	2.332	7.280	9.980	2.700	0.449	12.340	28.780
5-30	2- 6.0	332	2.634	2.239	7.520	9.980	2.460	0.410	10.914	24.445
5-45	2-18.0	332	2.405	2.044	7.630	9.980	2.350	0.391	10.267	20.997
6- 0	3-48.0	332	1.456	1.237	7.820	9.980	2.160	0.360	9.163	11.342
8-30	2-10.0	332	2.553	2.170	6.590	9.980	3.390	0.565	16.470	35.753
9- 0	1-32.0	332	3.608	3.067	6.840	9.980	3.140	0.523	14.976	45.939
9-15	1-37.0	332	3.422	2.909	7.020	9.980	2.960	0.493	13.897	40.430
9-30	1-47.0	332	3.102	2.637	7.060	9.980	2.920	0.486	13.657	36.019
10-30	2-56.0	332	1.886	1.603	7.760	9.980	2.220	0.370	9.510	15.249

POINT C-D FLOW

TIME OF MST HR MIN	STOP WCH INTERVAL MIN SEC	MH DIST FT	SURF VEL FT/SEC	AVE VEL FT/SEC	DIST TO LIQ LVL E(FT)	DIST TO INVERT F(FT)	G(FT) F-E=G	H G/D	AREA SQ.FT	Q CFS
4-45	12-12.0	584	0.797	0.678	7.600	10.380	2.550	0.430	11.625	7.683
5- 0	6-29.0	584	1.501	1.276	8.000	10.380	2.379	0.396	10.443	13.327
5-15	5-11.0	584	1.877	1.596	8.200	10.380	2.180	0.363	9.277	14.810
5-30	3-47.0	584	2.572	2.186	8.500	10.380	1.879	0.313	7.576	16.566
5-45	14- 3.0	584	0.692	0.588	8.650	10.380	1.729	0.288	6.751	3.975
8-15	3-52.0	584	2.517	2.139	7.950	10.380	2.429	0.404	10.737	22.975
9- 0	2-46.0	584	3.518	2.990	7.600	10.380	2.780	0.463	12.818	38.331
9-15	10-54.0	584	0.892	0.759	7.650	10.380	2.730	0.454	12.519	9.502
9-30	13-36.0	584	0.713	0.606	7.750	10.380	2.629	0.438	11.922	7.235

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Table 7

Sample Computation Of Pollutants

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 10-24-75 MONTROSE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
4-45	46.488	699.00						2-00	44.0
5- 0	37.253	620.00	41.870	15.00	663.85	149850.34	1560.94	4-00	74.0
5-15	28.780	469.00	33.016	15.00	554.18	98642.35	1027.52		
5-30	24.445	274.00	26.612	15.00	379.44	54438.42	567.06		
5-45	20.997	196.00	22.721	15.00	237.95	29147.77	303.62		
						TOTAL=	3459.15		

OVERFLOW POINT D SAMPLE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
4-45	7.883	316.00						2-20	12.0
5- 0	13.327	614.00	10.605	15.00	503.24	28771.66	299.70	6-10	25.0
5-15	14.810	702.00	14.068	15.00	660.31	50081.48	521.68		
5-30	16.568	485.00	15.688	15.00	587.42	49684.43	517.54		
5-45	3.975	169.00	10.271	15.00	423.85	23470.73	244.48		
						TOTAL=	1583.41	DIVERTED=1875.73	

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As would be noticed from computations in Table 6, a factor of 0.85 was used to convert the measured surface velocity to the mean velocity necessary for computation of flow rate. The factor of 0.85 is the average ratio of mean velocity to surface velocity based upon several hundred measurements of open channel flow velocities as stated in the Handbook of Hydraulics by Horace W. King. Due to the physical condition of the sewers, variation in sewer slope and other factors, the mean velocity is, at best, only an approximation.

Use of a current meter for velocity measurement was considered but it was concluded that high accuracy is not necessarily obtained through the use of a current meter. Although well suited to the measurement of stream velocities, current meters become entangled with rags, paper and other matter when placed in a flow of sanitary or combined sewage. The meter must then be removed from the sewer for cleaning, which could lengthen the desired time interval between successive velocity measurements.

With the intent of testing the mean velocity - surface velocity relationship, several methods of velocity measurement were employed at the Lawrence Avenue sewer during a storm condition. Surface velocities were obtained by the float measurement and current meter methods.

Mean velocities were obtained by recording the travel time of a flourescent dye. A required condition of the dye method is that the distance between manholes should be at least two hundred times the velocity. This condition was not met in the measurements performed at Lawrence Avenue. The current meter was also used for a mean velocity measurement; however, it eventually became clogged by suspended material present in the sewage. Also, the flow was constantly changing, resulting in unreliable comparison between measurements with two different methods. Therefore the data collected was inconclusive.

The presence of weirs in the sewers cause a backwater effect and a non-uniform flow condition. The depth of flow measured at the upstream end, therefore, does not represent the depth corresponding to the average velocity used in the computation of flow. This also introduces some error in the measurements. Therefore the measured data should not be viewed with the expectation of a very high degree of accuracy.

Although the Lawrence Avenue sewer was built as a 5 foot (1.52m) diameter circular section, it had distorted into a flatter section over the years of usage, particularly in the reach near the outfall. A survey was conducted to determine the correct dimensions of the sewer section in the reaches being used for sampling. The existing section between points A and B is shown in Figure 10 and the section between points C and D is shown in Figure 11. Correction factors for the flow area at various depths of the sewer section in the reaches A B and C D are listed in Table 8. Using these factors the discharge rates were adjusted to account for the distortion in the sewer section.

Computations for data processing were carried out with the help of a small computer program. The resulting data for the four selected storms of July 23, 1975, August 1, 1975, August 11, 1975 and October 24, 1975 are tabulated in Appendix A. In order to save space, only the data utilized in the calibration of the computer program has been included in the appendix. Measured data are also available with the City of Chicago on the pollutants COD, NH3-N, Organic-N, Settleable Solids and Coliforms for the selected storms. Partial data is available for other storms attempted during the monitoring period.

The precipitation data was picked at 5-minute intervals from the continuous recording charts received from the two gaging stations described earlier. The precipitation for the four storms used in the calibration is listed in Table 9.

F. CALIBRATION OF COMPUTER MODEL

As already mentioned, the computer simulation was performed with the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM), March 1975 Revision, Version II, on an IBM Model 370 computer. Runoff block, Transport block and Graph subroutine were called through the assignment of the Executive block.

Limits governed by each raingage were determined by Thiessen's polygon network. A 5-minute interval was used for the rainfall intensity input into the model. For convenience, the starting time of each rainfall was set at the beginning of the hour in which the rainfall started, with the insertion of some zero values for no rainfall period.

Input data for the SWMM were previously collected by Warren and Van Prag, Inc., a consulting engineering firm for the Chicago's Tunnel and Reservoir Plan (TARP). Only a small portion of the data was adjusted for the calibration.

A 5'-0" (1.52m) diameter sewer along Spaulding Avenue connects and relieves both the Montrose Avenue sewer and the

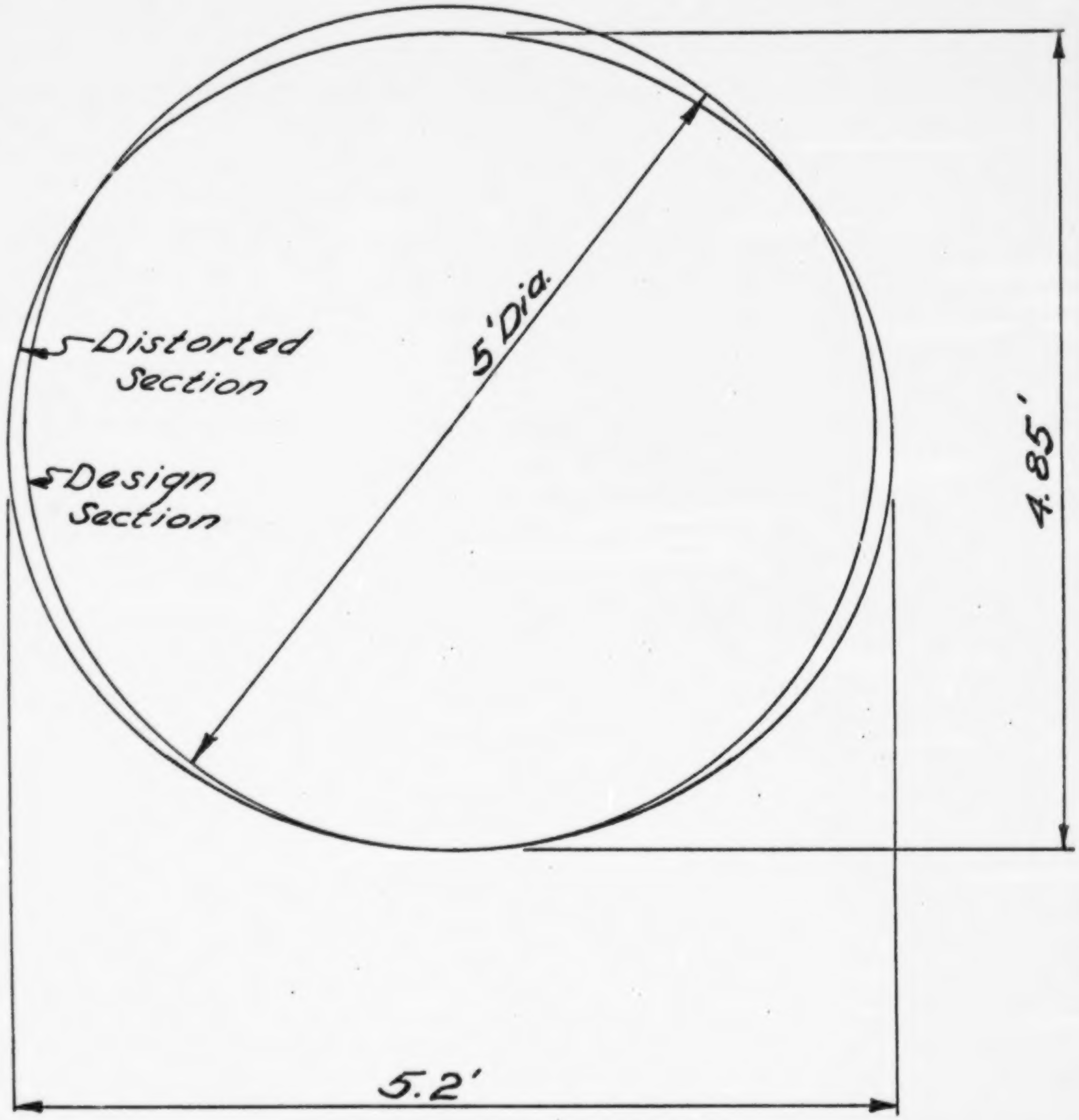
Distorted Section
Design Section
5' Dia.
4.85'
5.2'

Figure 10. Lawrence Ave. Sewer Section Near Outfall. (Reach AB).

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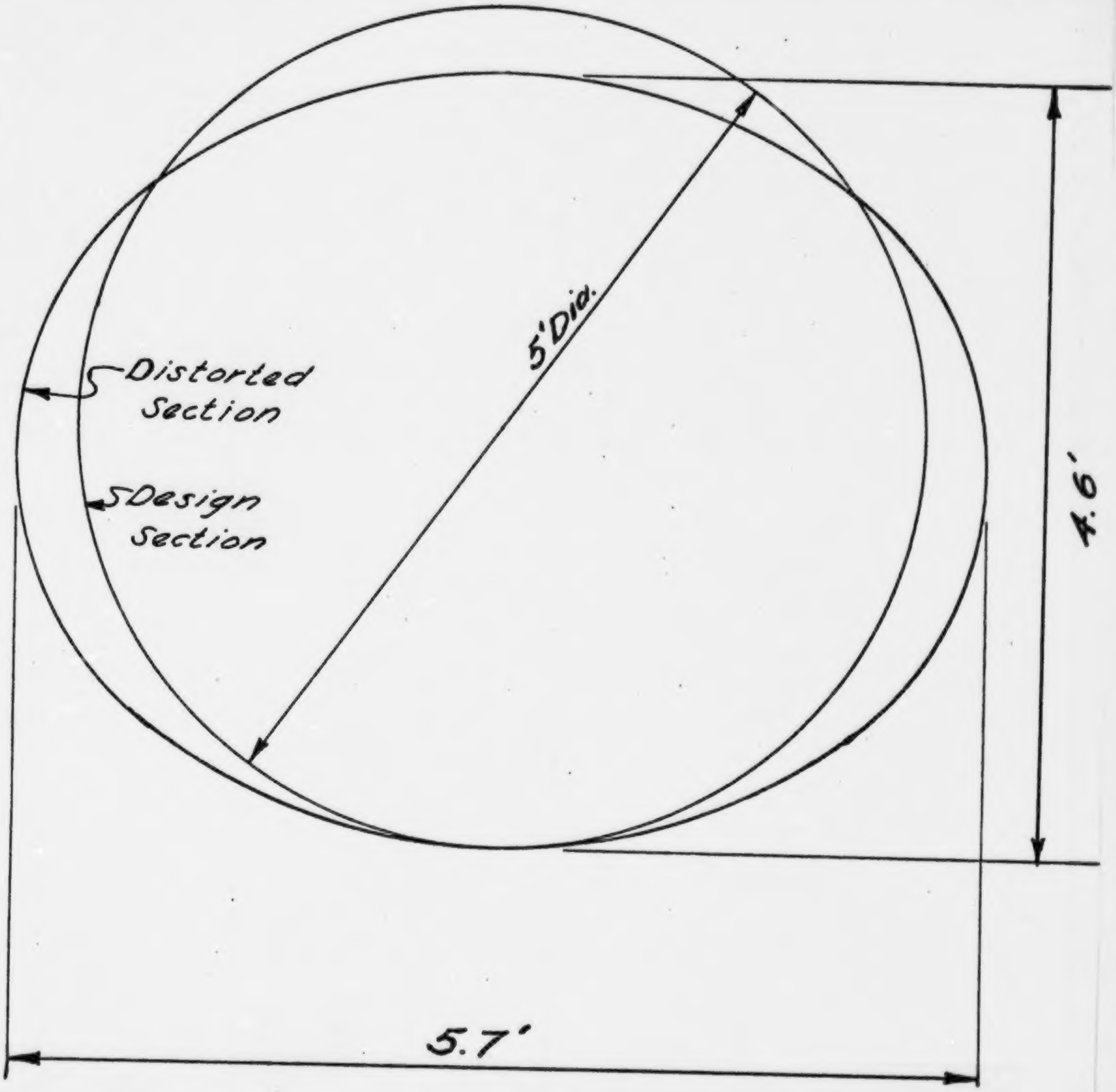
5'Dia.
Distorted Section
Design Section
4.6'
5.7'

Figure 11. Lawrence Ave. Sewer Section Near Outfall (Reach CD).

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BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
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Table 8

Area Correction Factors For Lawrence Avenue Sewer Section

Distance From Invert Ft.	Depth* Range At Point A Ft.	Area Factor
Reach A-B		
0 - 0.5	13.38 - 13.88	1.020
0.5 - 1.0	12.88 - 13.38	1.036
1.0 - 1.5	12.38 - 12.88	1.045
1.5 - 2.0	11.88 - 12.38	1.044
2.0 - 2.5	11.38 - 11.88	1.043
2.5 - 3.0	10.88 - 11.38	1.041
3.0 - 3.5	10.38 - 10.88	1.037
3.5 - 4.0	9.88 - 10.38	1.032
4.0 - 4.5	9.38 - 9.88	1.028
Reach C-D		
0 - 0.5	19.19 - 19.69	1.082
0.5 - 1.0	18.69 - 19.19	1.146
1.0 - 1.5	18.19 - 18.69	1.164
1.5 - 2.0	17.69 - 18.19	1.163
2.0 - 2.5	17.19 - 17.69	1.159
2.5 - 3.0	16.69 - 17.19	1.151
3.0 - 3.5	16.19 - 16.69	1.146
3.5 - 4.0	15.69 - 16.19	1.130
4.0 - 4.5	15.19 - 15.69	1.107

* Depth below manhole rim

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Table 9

Precipitation For Storms Used In Calibration

Date	Time	Rainfall - Inches North Branch	Mayfair
7/23/75	8:00 - 8:05 pm	.07	-
	8:05 - 8:10	.02	.02
	8:10 - 8:15	.02	.07
	8:15 - 8:20	-	.06
	8:20 - 8:25	.01	.02
	8:25 - 8:30	.01	.01
	8:30 - 8:35	.01	-
	8:35 - 8:40	.01	.01
	8:40 - 8:45	.01	-
	8:45 - 8:50	.01	.02
	8:50 - 8:55	.01	.01
	8:55 - 9:00	.01	.01
	9:00 - 9:05	-	.01
	9:05 - 9:10	-	.01
	9:10 - 9:15	.04	-
	9:15 - 9:20	.03	-
	9:20 - 9:25	.01	.04
	9:25 - 9:30	.01	.05
	9:30 - 9:35	.05	-
	9:35 - 9:40	-	.01
	9:40 - 9:45	.03	.01
	9:45 - 9:50	.01	.01
	9:50 - 9:55	.01	.01
	9:55 - 10:00	-	-
	10:00 - 10:05	-	-
	10:05 - 10:10	.01	-
	10:10 - 10:15	.02	-
	10:15 - 10:20	-	.01
	Total	.41	.39
8/1/75	6:30 - 6:35 pm	.03	-
	6:35 - 6:40	.05	-
	6:40 - 6:45	.18	-
	6:45 - 6:50	.07	.25
	6:50 - 6:55	.05	.23
	6:55 - 7:00	.08	-
	Total	.46	.48

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Table 9 continued

Date	Time		Rainfall - Inches North Branch	Mayfair
8/11/75	3:10 - 3:15	pm	.01	.07
	3:15 - 3:20		.01	.20
	3:20 - 3:25		.03	.09
	3:25 - 3:30		.26	.01
	4:10 - 4:15		-	.01
	4:35 - 4:40		.01	.01
	4:40 - 4:45		-	.02
	4:45 - 4:50		.01	.01
	4:50 - 4:55		.02	.01
	4:55 - 5:00		.01	-
	5:00 - 5:05		.01	.01
	5:05 - 5:10		.01	.01
	5:10 - 5:15		.01	.01
	5:15 - 5:20		.01	-
	5:20 - 5:25		.01	.01
		Total	.41	.47
10/24/75	12:20 - 12:25	pm	-	.03
	1:20 - 1:25		.01	-
	2:30 - 2:35		-	.04
	3:00 - 3:05		-	.03
	3:05 - 3:10		-	.14
	3:10 - 3:15		-	.04
	3:15 - 3:20		-	.06
	3:20 - 3:25		.01	-
	3:25 - 3:30		-	.01
	3:45 - 3:50		-	.01
	3:50 - 3:55		.04	-
	4:00 - 4:05		.05	-
	4:05 - 4:10		.05	-
	4:10 - 4:15		.05	-
	4:15 - 4:20		.11	.01
	4:20 - 4:25		.01	.01
	4:30 - 4:35		-	.01
	4:45 - 4:50		.08	-
	5:15 - 5:20		.01	-
	5:20 - 5:25		.01	-
	5:25 - 5:30		.01	-

contd.

Table 9 continued

Date	Time	Rainfall - Inches North Branch	 Mayfair
10/24/75	5:35 - 5:40 pm	.01	-
	6:40 - 6:45	-	.02
	6:45 - 6:50	-	.03
	6:50 - 6:55	-	.07
	6:55 - 7:00	-	.13
	7:00 - 7:05	-	.13
	7:05 - 7:10	-	.09
	7:10 - 7:15	-	.08
	7:15 - 7:20	-	.03
	7:20 - 7:25	-	.02
	7:25 - 7:30	-	.01
	7:30 - 7:35	-	.02
	7:35 - 7:40	-	.01
	7:40 - 7:45	.01	.02
	7:45 - 7:50	.01	.01
	7:50 - 7:55	.01	.02
	7:55 - 8:00	.08	.01
	8:00 - 8:05	.09	.01
	8:05 - 8:10	.09	.02
	8:10 - 8:15	.09	.01
	8:15 - 8:20	.06	-
	8:20 - 8:25	.02	-
	8:25 - 8:30	.01	-
	8:30 - 8:35	.02	.02
	8:35 - 8:40	.01	-
	8:40 - 8:45	.02	-
	8:45 - 8:50	.02	-
	8:50 - 8:55	.02	-
	8:55 - 9:00	.02	-
	9:00 - 9:05	.02	-
	9:05 - 9:10	.01	-
	9:10 - 9:15	.01	-
	9:40 - 9:45	.01	-
	9:45 - 9:50	-	-
	9:50 - 9:55	-	.01
	10:00 - 10:05	-	.01
	10:25 - 10:30	-	.01
	10:45 - 10:50	.01	-
	11:05 - 11:10	.01	-
		1.10	1.18

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BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
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Irving Park Road sewer (see Figure 5) to the Berteau Avenue sewer. During normal dry weather flow conditions, all flows continue to the MSD interceptor. In storm periods when the flows are large, an amount equal to approximately twice the dry weather flow continues to the interceptor, and the remainder is diverted to the waterway. In the SWMM model, a Type-20 flow divider was designed to simulate side weir diversion. Since the model cannot correctly simulate the storm event when surcharge and backwater conditions occur in the sewer system, the Type-20 flow divider cannot be used in this case. The only alternative is to define a drainage area for each of the sewer systems on the basis of calibration. Due to the fact that runoff is not affected solely by the drainage area, other factors have to be taken into consideration at the same time. The drainage area tributary to each sewer upstream of the connection structure varies and depends mainly on the magnitude and the intensity of the storm. Therefore, the drainage area boundary which will fit into storms of all magnitudes and intensities can at best be an approximation. After several trials, the final drainage area for each sewer system believed to best represent that system under a variety of conditions was established. The total drainage area for these three sewer systems under study is 1,311 acres (525 hectares).

A Type-18 flow divider was used for all intercepting structures. A comparison between the measured total flows and the measured overflows indicates that the amount of intercepted flow varies enormously depending on the conditions in the control structure and the intercepting sewer. The SWMM cannot simulate this situation accurately as it only permits a constant undiverted flow to the intercepting sewer. The constant intercepted flows used in the model were determined as a repernsentative average value after careful examination of the measured data.

The retention storage and the minimum infiltration rate of the drainage basin were determined through calibration. After a series of trial runs, 0.25 inch (0.63cm) retention storage for the pervious area and 0.50 inch per hour (1.27cm/hr) minimum infiltration rate were found to give satisfactory results.

Some of the input parameters had to be modified during the calibration process to match the pollution response of the model with the measured data. The SWMM generates the initial mass of dust and dirt (DD) as a function of total curb length and dry days. The mass of each pollutant is in turn generated as a fraction of the DD present. No attempt was made to change the pollutant loading factors used in the program due to lack of better values available. However, some of the curb lengths were adjusted. Also it was found necessary to increase the pollutional load either by increasing the number of catch basins per acre or the storage volume per catch basin. Being easier and convenient to change, the storage volume per catch basin was increased. The number used might seem unreasonably high but in reality it represents a higher number of catch basins per acre with a smaller and more realistic catch basin volume. The concentration of BOD of the stored water in each catch basin was set at 280 milligrams per liter.

The program was run for 150 time steps at 5-minute intervals for calculations and graphs.

Printouts from a typical calibration run are reproduced in Tables 10 thru 14. These show a sample of the input to the computer program for the three drainage areas used in the calibration. Table 10 shows the drainage basin parameters for each subcatchment. Table 11 shows the surface quality data. Table 12 lists the sewer network information. Table 13 shows the computation of dry weather flow by each subarea. Table 14 gives the factors used for the daily and hourly variations in the dry weather flow.

Appendix B, Figures B-1 thru B-24, show the plots of computed and measured overflow quantities for the Lawrence Avenue, Montrose Avenue and Irving Park Road drainage areas for the four storms used in the calibration. The rainfall hyetographs are also reproduced as used in the computer program. Where the measured values fall outside the graph they have been noted on the top of the graph.

In general, the computed hydrographs and pollutographs match fairly well with the measured data, particularly in quantitative terms. There still is not sufficient information available to model all the complex relationships between the urban storm water contaminants, their pollutional characteristics, and the manner in which they are transported during storms. Furthermore, the complexity of the sewer system in the Chicago area, the inability of the model to reproduce surcharge and backwater conditions, the lack of certain input factors and data, and in some cases doubtful field measurements, all make it increasingly difficult to obtain a better resemblance between the SWMM's computed values and the field recorded values.

Tables 15, 16 and 17 summarize the total quantities of overflows, BOD and Suspended Solids discharged to the waterway as computed and measured for the four storms studied.

Table 10

Calibration Run - Subcatchment Data

```
                S U B C A T C H M E N T   D A T A

SUBCATCH-  GUTTER    WIDTH    AREA   PERCENT   SLOPE   RESISTANCE FACTOR  SURFACE STORAGE(IN)  INFILTRATION    DECAY RATE  GAGE
MENT NO.  OR INLET   (FT)     (AC)   IMPERV.   FT/FT    IMPERV.   PERV.    IMPERV.   PERV.     RATE(IN/HR)      (1/SEC)     NO.
                                                                                             MAXIMUM MINIMUM
  1  131     31     1850.0    91.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  2  231     31      220.0    14.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  3  331     31      600.0    37.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  4  531     31       75.0     6.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  5  132     32     1650.0    94.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  6  232     32      240.0    15.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  7  332     32      600.0    36.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  8  532     32      130.0     7.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      2
  9  133     33     1650.0    94.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 10  233     33      260.0    15.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 11  333     33      600.0    36.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 12  533     33      130.0     7.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 13  151     51      780.0    22.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 14  251     51      360.0    16.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 15  351     51      710.0    20.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 16  551     51      460.0    13.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 17  105      5      670.0    18.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 18  205      5      300.0     8.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 19  305      5      440.0    17.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 20  505      5      370.0    16.0    45.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 21  160     60      330.0   217.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 22  260     60       80.0    32.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 23  560     60       80.0     6.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 24  148     48      630.0    16.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 25  348     48      165.0     5.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 26  548     48      195.0     6.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 27  146     46      660.0    18.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 28  346     46      160.0     6.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 29  546     46      180.0     5.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 30  144     44      660.0    16.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 31  344     44      150.0     4.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 32  544     44      180.0     5.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 33  142     42      660.0    18.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 34  342     42      150.0     4.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 35  542     42      180.0     5.0    44.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 36  165     65      390.0   100.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 37  365     65       85.0    13.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 38  565     65       15.0    15.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 39  163     63      400.0    75.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 40  363     63       85.0    15.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 41  563     63       10.0     3.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 42  161     61      400.0    74.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 43  361     61       85.0    14.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 44  561     61       10.0     2.0    40.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 45  159     59      190.0    12.0    28.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 46  259     59      220.0    15.0    28.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 47  359     59       54.0     6.0    28.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 48  459     59       94.0     7.0    28.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
 49  559     59      530.0    35.0    28.0    0.014    0.013    0.250    0.062    0.250    3.00    0.50    0.00115      1
TOTAL NUMBER OF SUBCATCHMENTS,  49
TOTAL TRIBUTARY AREA (ACRES),  1311.00
```

Table 11

Calibration Run - Surface Quality Data

```
NUMBER OF CONSTITUENTS        8

NUMBER OF DRY DAYS          3.6

STREET CLEANING FREQ      90.0 DAYS

PASSES PER CLEANING           1

STD CATCHBASIN VOLUME   175.00 FT3

CATCHBASIN CONTENTS BOD  280.0 MG/L

METHOD FOR CALCULATING SS
  SPECIAL TECHNIQUE
  SAME AS IN ORIGINAL
  RELEASE 1 OF THE SWMM
  ISS = 1
```

```
WATERSHED QUALITY DEFINITIONS

SUBAREA   LAND USE   TOTAL  GUTTER         NUMBER  OF
 NUMBER    CLASS    LENGTH*10**2 FT.     CATCHBASINS

  1  131     1          337.00              91.00
  2  231     2           31.00              14.00
  3  331     3          116.00              31.00
  4  531     5            6.00               5.00
  5  132     1          337.00              94.00
  6  232     2           31.00              15.00
  7  332     3          117.00              34.00
  8  532     5            7.00               7.00
  9  133     1          338.00              94.00
 10  233     2           31.00              15.00
 11  333     3          117.00              34.00
 12  533     5            7.00               7.00
 13  151     1           64.00              22.00
 14  251     2          220.00              10.00
 15  351     3           62.00              26.00
 16  551     5           17.00              13.00
 17  105     1           64.00              14.00
 18  205     2          174.00               8.00
 19  305     3           57.00              17.00
 20  605     5           13.00              16.00
 21  156     1          763.00             217.00
 22  356     3          102.00              32.00
 23  656     5            2.00               4.00
 24  148     1           65.00              15.00
 25  348     3           17.00               5.00
 26  548     5            5.00               6.00
 27  146     1           65.00              18.00
 28  346     3           17.00               4.00
 29  546     5            8.00               5.00
 30  144     1           65.00              18.00
 31  344     3           16.00               4.00
 32  544     5            4.00               5.00
 33  142     1           64.00              18.00
 34  342     3           16.00               4.00
 35  542     5            4.00               5.00
 36  165     1           85.00             106.00
 37  365     3           22.00              12.00
 38  665     5           24.00              19.00
 39  163     1          101.00              75.00
 40  363     3           23.00              15.00
 41  663     5           17.00               3.00
 42  161     1          101.00              74.00
 43  361     3           23.00              14.00
 44  661     5           17.00               3.00
 45  159     1           41.00              12.00
 46  259     2           26.00              18.00
 47  359     3           15.00               4.00
 48  459     4           18.00               7.00
 49  559     5           35.00              35.00
```

Table 12

Calibration Run - Sewer Element Data

```
          NUMBER OF ELEMENTS  =    41
          NUMBER OF TIME INT  =   150
          TIME INTERVAL       =   300.0 SECONDS

 * * * * *  ELEMENT PARAMETERS  * * * * *

 EXT  TYPE  DESCRIPTION      SLOPE    DISTANCE  MANNING    GEOM1  GEOM2  GEOM3  NUMBER   AFULL    QFULL    QMAX    SUPER CRITICAL
 ELE                        (FT/FT)     (FT)   ROUGHNESS   (FT)   (FT)   (FT)     OF    (SQ FT)   (CFS)    (CFS)   FLOW WHEN LESS
 NUM                                                                            BARRELS                            THAN 95% FULL?
   1   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
   2    1   CIRCULAR        0.0009     330.0    0.0130      5.0    0.0    0.0     1.0    19.635   77.854   84.082       NO
   3   18   FLOW DIVIDER    0.0          0.0    0.0        16.0    0.0  111.0     1.0     0.0      0.0      0.0
   4    1   CIRCULAR        0.0013    1650.0    0.0130      5.0    0.0    0.0     1.0    19.635   93.430  100.904       NO
   5   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
   6    1   CIRCULAR        0.0019    2310.0    0.0130      4.5    0.0    0.0     1.0    15.904   84.810   91.594       NO
  51   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
   7    1   CIRCULAR        0.0019    2970.0    0.0130      4.5    0.0    0.0     1.0    15.904   84.810   91.594       NO
  33   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
   8    1   CIRCULAR        0.0020    2640.0    0.0130      4.0    0.0    0.0     1.0    12.566   64.893   70.084       NO
  32   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
   9    1   CIRCULAR        0.0014    2640.0    0.0130      3.8    0.0    0.0     1.0    11.045   45.532   49.175       NO
  31   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
 111   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  34   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  40    1   CIRCULAR        0.0016     925.0    0.0130      6.0    0.0    0.0     1.0    28.274  168.654  182.146       NO
  42   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  41   18   FLOW DIVIDER    0.0          0.0    0.0        16.0    0.0  135.0     1.0     0.0      0.0      0.0
  43    1   CIRCULAR        0.0005     990.0    0.0130      6.0    0.0    0.0     1.0    28.274   94.973  102.571       NO
  44   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  45    1   CIRCULAR        0.0009     550.0    0.0130      6.0    0.0    0.0     1.0    28.274  126.685  136.819       NO
  46   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  47    1   CIRCULAR        0.0008    1155.0    0.0130      6.0    0.0    0.0     1.0    28.274  121.601  131.329       NO
  48   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  49    1   CIRCULAR        0.0008    4600.0    0.0130      5.5    0.0    0.0     1.0    23.758   94.939  102.534       NO
  50   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
 135   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  55   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  56    1   CIRCULAR        0.0010     860.0    0.0130      6.0    0.0    0.0     1.0    28.274  130.885  141.356       NO
  57   18   FLOW DIVIDER    0.0          0.0    0.0        30.0    0.0  155.0     1.0     0.0      0.0      0.0
  58    1   CIRCULAR        0.0008    1320.0    0.0130      6.0    0.0    0.0     1.0    28.274  120.108  129.717       NO
  59   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  60    1   CIRCULAR        0.0008     990.0    0.0130      6.0    0.0    0.0     1.0    28.274  120.857  130.525       NO
  61   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  62    1   CIRCULAR        0.0008     990.0    0.0130      6.0    0.0    0.0     1.0    28.274  120.857  130.525       NO
  63   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
  64    1   CIRCULAR        0.0010    2100.0    0.0130      5.5    0.0    0.0     1.0    23.758  107.009  115.570       NO
  65   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
 155   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
 100   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
 101   16   MANHOLE         0.0          0.0    0.0         0.0    0.0    0.0     1.0     0.0      0.0      0.0
```

Table 13

Calibration Run - Dry Weather Flow Results

A(BOD) : 864.86 LBS/DAY/CFS
A(SS) : 873.54 LBS/DAY/CFS
A(COLI) : 2.71E+07 MPN/DAY PER CAPITA
ADWF : 22.76 CFS

KNUM	INPUT	DWF CFS	+ INFIL CFS	= DODWF CFS	KLAND	DWBOD LBS/MIN	DWSS LBS/MIN	TCYPOP PERSONS	BODCONC MG/L	SSCONC MG/L	COLIFORMS MPN/100ML
1	31	0.074	0.021	0.095	1	0.04	0.04				
2	31	0.015	0.004	0.019	2	0.01	0.01				
3	31	0.481	0.137	0.618	2	0.23	0.23				
4	31	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		0.57	0.16	0.73		1.37 LBS	1.38 LBS	8239.	100	101	1.25E+04
5	32	0.073	0.021	0.093	1	0.03	0.04				
6	32	0.015	0.004	0.019	2	0.01	0.01				
7	32	0.528	0.150	0.677	2	0.25	0.26				
8	32	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		1.18	0.34	1.52		2.81 LBS	2.88 LBS	16817.	100	101	1.23E+04
9	33	0.073	0.021	0.093	1	0.03	0.04				
10	33	0.015	0.004	0.019	2	0.01	0.01				
11	33	0.528	0.150	0.677	2	0.25	0.26				
12	33	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		1.80	0.51	2.31		4.32 LBS	4.37 LBS	25395	100	101	1.22E+04
13	51	0.033	0.009	0.042	1	0.02	0.02				
14	51	0.017	0.005	0.022	2	0.01	0.01				
15	51	0.310	0.088	0.398	2	0.15	0.15				
16	51	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		2.16	0.61	2.77		5.19 LBS	5.24 LBS	30365	100	101.	1.21E+04
17	5	0.033	0.009	0.042	1	0.02	0.02				
18	5	0.017	0.005	0.022	2	0.01	0.01				
19	5	0.264	0.075	0.339	2	0.13	0.13				
20	5	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		2.47	0.70	3.18		5.94 LBS	6.00 LBS	34919	100	101	1.22E+04

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Table 13 (Contd.)

21	46	0.270	0.077	0.346	1	0.16	0.16				
22	46	0.076	0.022	0.100	2	0.05	0.05				
23	46	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		2.82	0.80	3.62		6.98 LBS	7.05 LBS	36885.	103	104.	1.13E+04
24	46	0.029	0.008	0.037	1	0.02	0.02				
25	46	0.062	0.018	0.080	2	0.04	0.04				
26	46	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		2.91	0.83	3.74		7.26 LBS	7.33 LBS	38721.	104.	105.	1.15E+04
27	44	0.029	0.008	0.037	1	0.02	0.02				
28	44	0.062	0.018	0.080	2	0.04	0.04				
29	44	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		3.00	0.85	3.85		7.53 LBS	7.61 LBS	40553	104	105	1.17E+04
30	42	0.029	0.008	0.037	1	0.02	0.02				
31	42	0.062	0.018	0.080	2	0.04	0.04				
32	42	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		3.09	0.88	3.97		7.80 LBS	7.88 LBS	42385.	105	106.	1.18E+04
33	63	0.316	0.090	0.406	1	0.15	0.15				
34	63	0.233	0.066	0.299	2	0.14	0.14				
35	63	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		3.64	1.03	4.68		9.45 LBS	9.55 LBS	49585.	108.	109.	1.18E+04
36	61	0.096	0.027	0.123	1	0.06	0.06				
37	61	0.217	0.062	0.279	2	0.13	0.12				
38	61	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		3.95	1.12	5.08		10.39 LBS	10.49 LBS	54576.	109.	110.	1.24E+04
39	59	0.012	0.003	0.016	1	0.01	0.01				
40	59	0.019	0.005	0.024	2	0.01	0.01				
41	59	0.062	0.018	0.080	2	0.04	0.04				
42	59	0.109	0.031	0.139	2	0.07	0.07				
43	59	0.0	0.0	0.0	5	0.0	0.0				
	SUBTOTALS										
		4.16	1.18	5.34		10.99 LBS	11.11 LBS	59080.	110.	111.	1.23E+04
44	50	0.155	0.044	0.198	1	0.07	0.08				

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Table 14

Calibration Run - Daily and Hourly Flow and Quality Variation Factors

```
         DAILY AND HOURLY CORRECTION FACTORS
                  FOR SEWAGE DATA

   DAY          DVDWF      DVBOD      DVSS       DVCOLI

     1          0.700      0.980      1.100
     2          0.990      0.790      0.810
     3          1.040      0.980      1.140
     4          1.150      1.330      1.090
     5          1.130      1.050      0.970
     6          1.110      0.940      0.800
     7          0.880      0.930      1.140

  HOUR

     1          0.760      0.860      0.625      1.100
     2          0.710      0.710      0.350      0.640
     3          0.700      0.600      0.350      0.450
     4          0.700      0.410      0.195      0.870
     5          0.710      0.460      0.195      0.540
     6          0.810      0.490      0.270      0.480
     7          1.020      0.720      0.270      1.290
     8          1.090      0.870      1.330      1.180
     9          1.150      0.770      1.330      1.370
    10          1.180      1.570      1.680      1.490
    11          1.160      1.020      1.590      1.300
    12          1.180      0.870      1.590      1.120
    13          1.170      0.910      1.590      0.890
    14          1.170      0.940      1.440      0.580
    15          1.160      1.070      1.440      0.450
    16          1.160      1.070      1.440      0.670
    17          1.130      1.140      1.440      0.960
    18          1.130      0.990      1.170      1.180
    19          1.120      1.450      1.170      0.840
    20          1.080      1.160      1.090      1.010
    21          1.030      1.550      1.090      2.820
    22          1.000      1.290      0.860      1.770
    23          0.890      0.990      0.860      0.840
    24          0.820      1.600      0.635      0.710
```

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Table 15

Summary Of Computed and Measured Overflows

Storm Date	Drainage Area	Computed Overflow 1000 CF	Measured Overflow 1000 CF	Difference %
7/23/75	Lawrence Ave.	243	233	+ 4.2
	Montrose Ave.	57	60	- 4.3
	Irving Park Rd.	45	60	-24.3
	Total	345	353	- 2.1
8/01/75	Lawrence Ave.	350	356	- 1.8
	Montrose Ave.	107	97	+10.0
	Irving Park Rd.	104	87	+18.5
	Total	561	540	+ 3.6
8/11/75	Lawrence Ave.	317	311	+ 2.1
	Montrose Ave.	66	80	-17.7
	Irving Park Rd.	49	65	-25.0
	Total	432	456	- 5.3
10/24/75	Lawrence Ave.	927	842	+10.0
	Montrose Ave.	324	298	+ 8.7
	Irving Park Rd.	279	240	+16.2
	Total	1,529	1,380	+ 9.8
	Total for three areas and four storms	2,867	2,729	+ 5.0

Table 16

Summary of Computed and Measured BOD

Storm Date	Drainage Area	Computed BOD Pounds	Measured BOD Pounds	Difference %
7/23/75	Lawrence Ave.	1,706	1,647	+ 3.6
	Montrose Ave.	502	497	+ 1.0
	Irving Park Rd.	356	292	+21.9
	Total	2,564	2,436	+ 5.3
8/01/75	Lawrence Ave.	2,160	2,592	-16.7
	Montrose Ave.	778	691	+12.6
	Irving Park Rd.	837	621	+34.8
	Total	3,775	3,904	- 3.3
8/11/75	Lawrence Ave.	1,890	1,674	+12.9
	Montrose Ave.	356	346	+ 2.9
	Irving Park Rd.	324	248	+30.6
	Total	2,570	2,268	+13.3
10/24/75	Lawrence Ave.	3,078	3,996	-23.0
	Montrose Ave.	1,069	1,004	+ 6.5
	Irving Park Rd.	1,080	1,058	+ 2.1
	Total	5,227	6,058	-13.7
Total for three areas and four storms		14,136	14,666	- 3.6

Table 17

Summary of Computed and Measured Suspended Solids

Storm Date	Drainage Area	Computed SS Pounds	Measured SS Pounds	Difference %
7/23/75	Lawrence Ave.	3,510	2,754	+27.4
	Montrose Ave.	648	788	-17.8
	Irving Park Rd.	443	464	- 4.5
	Total	4,601	4,006	+14.9
8/01/75	Lawrence Ave.	9,828	9,720	+ 1.1
	Montrose Ave.	2,376	2,214	+ 7.3
	Irving Park Rd.	2,160	1,944	+11.1
	Total	14,364	13,878	+ 3.5
8/11/75	Lawrence Ave.	5,832	5,184	+12.5
	Montrose Ave.	945	1,026	- 7.9
	Irving Park Rd.	1,512	1,404	+ 7.7
	Total	8,289	7,614	+ 8.9
10/24/75	Lawrence Ave.	11,340	12,096	- 6.3
	Montrose Ave.	3,132	2,997	+ 4.5
	Irving Park Rd.	2,403	2,484	- 3.3
	Total	16,875	17,577	- 4.0
Total for three areas and four storms		44,129	43,075	+ 2.4

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For computation of volume if the starting or ending of the overflow was not known, the measured plot was assumed to follow the pattern of the computed plot, keeping the time base approximately the same. For the purpose of this study the overall quantitative impact of the overflows on the receiving waters was considered more important than the exact timings and concentrations of the overflows. This is why more emphasis was given during calibration to narrowing the difference between computed and measured quantities for the three areas as a whole rather than matching the plots shown in Appendix B. Considering the method and accuracy of measurements and the accuracy of the model an agreement within 10% between the computed and measured values was considered reasonable. Also the impact for all storms together being more important than for an isolated storm event, an attempt was made to match the aggregate quantities for all of the storms considered. It can be noted from Tables 15, 16 and 17 that the difference between the computed and measured quantities for flows, BOD and SS, is 5.0%, -3.6% and 2.4% respectively, which is considered a very good agreement.

SECTION V

PHASE II MONITORING - POSTPROJECT CONDITIONS

A. PROBLEMS DELAYING COMPLETION OF PUMPING STATION

Problems delaying completion of the pumping station can be divided into several, although not entirely separate, catagories. As is frequently the case, compensating benefits were derived which enabled successful completion of another similar project, namely the Nashville Avenue Sewer System, including its related pumping station.

1. Submersible Pumps

The high-head, high-capacity pumps required for this project, coupled with the requirement that they be submersible, restricted the list of available manufacturers, and in fact only one company was available at that time which could supply the required product. The KSB Pump Company, located in Germany, was the supplier and is world-renowned in its field, perhaps at that time without peer. During the lengthy period required by them to develop the specialized pumps, the concreting of the main shaft was completed. In addition, all of the corollary equipment had been purchased by the prime contractor, including the specified cables manufactured by the General Electric Company, and the cable reels, which were designed for cables of a specific diameter and bending radius. KSB notified the City, after the above was accomplished, that the GE cables were considered by them to be unsuitable for use with the KSB pumps because the cables were allegedly susceptible to water leakage through the outer coating, and could cause damage to the pumps. KSB said they would not guarantee their pumps if GE cables were installed, but if their German cables were used, the guarantee would be honored. Upon investigation by City engineers, it was established that the German Cable could not be used because of the inordinate costs involved in changing related equipment, and our consulting engineers stated that in their opinion the cables as specified were adequate. The German cables also lacked approval by the Underwriters Laboratory, but approval could have been obtained upon application and testing. KSB decided this process would take too long. The City's Bureau of Electrical Inspection would not accept electrical equipment unless it had a UL approval. KSB proposed that additional splice boxes be mounted atop each pump, one for the power cable and the other for the control cable. Within these boxes the German cable would be spliced to the American cable. Using this method, KSB said they would guarantee their pumps against water damage, but not the cable. The proposal was accepted by the City. Three pumps were then installed into their proper positions. After being in operation for about six months, the control equipment indicated that one pump was not operating. That pump was removed and the junction chamber and the cable were discovered to be damaged by an internal explosive force. While an evaluation of the cause of the damage was being made, another pump was damaged. The second pump damage was only within the junction chamber. KSB maintained that the damage was caused by the allegedly-defective GE cable, but nonetheless rectified the pump damage at their cost. City engineers determined that the damage was not the fault of the splice box, but rather of a water leakage through the sealant in the splice tube whereby water entered the upper junction chamber. New boxes were fabricated. Because cable damage had also occurred, additional research was made to select different cables which would be more water-resistant under the high water pressures. New cables manufactured by Okonite were selected. The new control cable, however, had a much larger diameter than the GE cable, and could not be wound on the available cable reel without being damaged. The cable weight was also too great for the cable reel torque motor. Therefore, larger control cable reels were purchased and the torque motors reconnected in delta to give increased power. Three pumps were reinstalled and have been functioning manually for over a year as of October 1981. The fourth pump has not yet been installed because of the necessity to clean out the bottom of the shaft for reasons described later in this report.

2. Control System

The bubbler system used to monitor water elevations within the shaft, thereby controlling start-stop elevations of the pumps, became inoperative. Initially, the 1/4-inch plastic tube within the steel covering tube became clogged with material suspended in the flows, so that the pump operational elevations became inaccurate. New 1/2-inch tubes were installed, but these became pinched at the top due to their own hanging weight. A series of intermittent supports were added, solving that problem. The compressor supplying air to the bubbler system became worn and had to be replaced, and the original one retained to be used as a standby.

Another potentially serious problem was the interfacing between the power panel and the control panel. The units were manufactured by different companies, and each unit had its own wiring diagram. It was discovered after the connections were made that although the power was switched off in the power panel, it was possible to reactivate the power panel by use of a supposedly unrelated switch on the control panel while repairs or adjustments were being made. This was a potentially hazardous condition which had to be remedied. The City's engineers designed a revised circuitry and the problem was solved.

3. Flows From The Argyle Street Sewer

A section of old brick sewer in Argyle Street collapsed during 1977, necessitating finding another outlet for the flows in that sewer. Due to the emergency nature of the circumstances, the weir to the new 60-inch (1.52m) Drake Avenue Sewer leading to the dropshaft at Lawrence Avenue was removed, allowing all flows from the Argyle Street Sewer to enter the tunnel. Because of the inability to pump out the tunnel, material accumulated and remained for an extended period of time. Because the old brick sewer passed under two houses, condemnation proceedings were necessary due to the unwillingness of the owners to sell, which resulted in approximately an 18-month delay before the necessary repairs could be completed. Part of the material has been removed by pumping, but material remains in the recess reserved for Pump Number 4. That pump is now ready to install, but must wait until the material is removed, as labor forces need to go to the bottom of the shaft to place the pump into its recessed position.

4. Installation of Pumps

Installation of each pump takes approximately four hours and involves a crew of about eleven men, with at least two more for Pump No. 4. One major problem occurred when a pump was being installed after the Argyle Street sewer flows were in the tunnel. The pump did not seat fully on its guide cone, and the pump was momentarily started in an attempt to dislodge the material around the cone. The pump spun loose, snapped a guide cable which fell into the shaft and damaged the electrical cables. As a result, a diver had to be lowered to retrieve the guide cable, and the entire process of resplicing the cables had to be done. The resplicing involved shipping the entire pump to a factory, removing and cleaning the splice box, cutting away the damaged cable and resplicing under controlled conditions, then returning the pump and cable to the job site for reinstallation.

5. Elevator Problems

Under the construction contract an automatic elevator was installed in the main shaft for the purpose of lowering men and small equipment into the shaft in a convenient and inexpensive manner. The elevator functioned adequately until debris accumulated on the elevator guides and counterweights. Most of this material could be hosed off by means of the water cannon supplied for purposes of cleaning the shaft walls and equipment. The cannon was unable to reach the upper areas with sufficient force to clean all material from the elevator equipment, however. The elevator was cleaned and made operational at least once, but the problem is persistent.

6. Repair of Miscellaneous Damaged Equipment

Over a period of time various other items in the main shaft had been damaged or had vanished. These included damaged items such as the trashracks, the trashrack roof and related beam and lifting cables, the bubbler pipes, the water cannon, the air supply pipe and the overflow samplers. Missing equipment included sections of the trashrack roof grating and the landings for the emergency ladders on the wall.

During a recent (May 1981) storm, the Resident Engineer observed the extremely rapid rise of water in the main shaft, prior to which most items of equipment in the shaft were noted to be intact. After pumpdown it was discovered that the bubbler tubes were again damaged and the air supply pipe was crushed at the top and bottom levels, although the intermediate portions were intact. Measures are being taken to protect and/or reinforce these members.

In the winter 1980-1981 severe damage had occurred to the trashracks and trashrack roof. It was discovered that due to a clogged drain pipe in the outfall chamber, water had accumulated because of slow infiltration through incompletely closed tide gates at the river. This water gradually froze and when large volumes of ice had accumulated it fell on the equipment below. Additionally, water had frozen at lower levels and jammed some equipment. In one of the more noteworthy incidences, a trashrack had gradually been raised about ten feet by the ice and had become lodged askew in its guides. The trashrack lifting beam was hooked to the trashrack and the unit wrenched loose. The chain snapped and the assembly fell to the bottom of the shaft, damaging both the trashrack and the lifting beam. The trashrack was repaired and the rollers on the lifting beam respaced to give greater freedom of movement.

The valve chamber containing the ball valves flooded because of a design oversight of omitting a thrust plate around the pipes within the concrete chamber wall, which permitted movement of the discharge pipe due to the thrust of the water around the pipe bend. That problem has been corrected. Flooding of the valve chamber also damaged the sampling pump, which had to be replaced.

7. Changes in Supervisory Personnel

During the period of construction of the entire Lawrence Avenue System, a span of approximately twelve years, both the City of Chicago and the Contractor had to replace their resident engineers on the job due to retirement, transfers and deaths. This apparently caused problems in the control of the job during transition periods, including maintenance of records regarding reasons for making certain decisions, reporting of problems which may have occurred, co-ordinating deliveries of material, and other significant matters.

B. DATA COLLECTION

It was originally planned to monitor the three selected outfalls and the Lawrence Avenue tunnel outfall for postproject conditions. This would have provided additional data to substantiate model calibration. Difficulties encountered in the preproject monitoring clearly pointed towards a shift from manual operation to installation and use of automatic sampling equipment. In May and July 1976 the matter of postproject monitoring was discussed in meetings between the personnel from the City of Chicago and the USEPA. In view of the study objectives, the difficulties in field measurements, and the costs involved, it was resolved that postproject data should be gathered at an outfall representative of the general project area and that an automatic sampling equipment should be installed for this purpose. This is in addition to monitoring the tunnel outfall as planned.

As described in the preceding section, the completion of the Lawrence Avenue Sewer System was continually delayed due to one problem after another. In December of 1980 the USEPA indicated that the Final Report on this project could not be delayed beyond 1981. Consequently it was decided that sampling of the Lawrence Avenue high-level sewer would not be necessary and the postproject evaluation should be based on computer modeling, ancillary sampling, and documentation of the actual operating and maintenance experience with the Lawrence Avenue Underflow Sewer System.

It was anticipated at that time that the system would be completely operational by the end of March 1981 and some sampling of the pumped flow to the interceptor and overflow to the river would be possible, along with some quantitative data for mass balance computations for actual storm events. However, the contractor was not able to make the automatic operation of the pumping station functional. The recording instruments and sampling equipment were also not operable. A City work force was mobilized to inspect and make necessary repairs to the sampling equipment.

As described earlier, flows from the Argyle Street sewer had been routed through the Lawrence Avenue tunnel for an extended period. Since the pumps were not operational at that time, the flows were simply retained in the tunnel, resulting in sedimentation of solids to the bottom. This pollution load must be cleaned up before the tunnel system goes in normal operation.

In April 1981 the tunnel system was dewatered and the outfall shaft was inspected for the first time following the winter. It was found that the trashrack roof and the upstream trashrack had sustained major damage. Also, the air vent pipe and the bubbler tube were again damaged. During the winter, water seeping through the tide gates formed sheets of ice on the shaft wall. With the advent of warmer weather, the ice thawed and fell, causing damage to equipment in the shaft. The trashrack roof was caved in and large sections were sheared off, dropping to the bottom of the shaft. The damaged trashrack had been lifted approximately ten feet, where it became distorted and stuck in the guides. However, all three pumps which were installed were still operable. Since broken pieces of the trashrack could possibly be in the sump, they could damage the pumps. Therefore, further pumping was discontinued pending repairs to damaged members.

Because pumping could not be accomplished due to the possible presence of debris in the shaft bottom, and the accumulated sediments in the tunnel could not be removed until the tunnel was dewatered, it was not possible to complete the sampling program. The postproject evaluation was therefore carried out utilizing the model calibrated with the previously collected data, as described in Section VI.

The postproject sampling of groundwater was performed, however, for the period of May through August 1981, as described in Section VI-D.

SECTION VI

EVALUATION OF SYSTEM PERFORMANCE

A. PERIOD OF ANALYSIS

It would be desirable to have an extended period of data or at least one complete year's data for an average hydrologic year, in order to evaluate the system performance. The specific version of the USEPA's Storm Water Management Model used in this study is primarily designed for use with isolated storm events. It cannot be used for continous simulation due to prohibitive computer time and costs involved and certain other limitations inherent in the program. Therefore the period of analysis had to be selected such that it could, in some way, be related and extrapolated to a more comprehensive data.

The City of Chicago had gathered continuous hourly precipitation data from a number of gages in the Chicago metropolitan area for the years 1949 through 1973 for the design of the Tunnel and Reservoir Plan (TARP). A major portion of the Lawrence Avenue Sewer System drainage area is served by the Mayfair Pumping Station raingage. Additional data for this gage was obtained from the City's Department of Water for the years 1974 through 1980. The annual average precipitation for the 32 years of data is approximately 35.00 inches (87.6 cm). Total precipitation for the Mayfair gage in 1977 was 36.07 inches (91.6 cm) and continuous recording charts were available for both the gages serving the study area. Therefore it was decided to use the 1977 precipitation data for evaluation of system performance.

The time of concentration for the modeled areas is approximately 3 hours. A storm event was assumed to consist of a precipitation period having not more than three hours of intervening dry weather. Based on past experience and calibration runs it was assumed that a precipitation of less than 0.15 inch (0.38 cm) would generally not cause an overflow to occur at any of the outfalls under the preproject conditions. Therefore all such storms could be omitted from the evaluation. Storms having accumulations of 0.15 inch (0.38 cm) or greater were divided into eleven (11) categories based on total precipitation in increasing order of magnitude. These storm categories with associated precipitation range and 1977 recurrence frequency are listed in Table 18.

As is evident from Table 18, there were no storms in categories 7, 8 and 11. From each of the remaining 8 categories

Table 18

Precipitation Range For Selected Storm Categories

Storm Category	Precipitation Range Inches	Recurrence Frequency in 1977
1	0.15 - 0.39	23
2	0.40 - 0.59	9
3	0.60 - 0.79	8
4	0.80 - 0.99	2
5	1.00 - 1.19	2
6	1.20 - 1.39	3
7	1.40 - 1.59	0
8	1.60 - 1.79	0
9	1.8 - 1.99	3
10	2.0 - 2.19	2
11	2.20 and higher	0

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one storm was selected for computer runs. It was attempted that as much as possible the precipitation depth for the selected storm would fall in the middle of the precipitation range for that particular category. For instance, the selected storm for category 4 has a precipitation of 0.92 inch (2.34 cm) while the precipitation range is 0.80 inch (2.03 cm) to 0.99 inch (2.51 cm). The 8 storms used in the evaluation runs are listed in Table 19.

B. COMPUTER SIMULATION

With the SWMM computer program calibrated, computer simulation was performed for the study area for the selected period of analysis. The computer runs simulated runoff from the overall area affected by the Lawrence Avenue Sewer System, as shown in Figures 5 and 12.

Nine drainage basins were simulated for preproject conditions as demarcated by numbers 1 through 9 in Figure 5. As stated earlier, basins 1 and 2 contribute only dry weather flow and a small quantity of intercepted combined flow during storms to the downstream basins. The remaining seven basins, 3 through 9, were actually used in comparison of preproject and postproject overflows.

Figure 12 shows the ten drainage basins simulated for postproject conditions. Principal sewers in each basin are also shown. Basins 1 and 2 are unchanged, while the drainage areas for basins 3 through 9 are modified so that parts of these basins become tributary to the Lawrence Avenue Tunnel System which is represented in Figure 12 by basin 10. Thus, ten drainage basins were simulated for postproject conditions, of which eight basins, 3 through 10, were actually used in comparison of preproject and postproject overflows.

As described in Section IV-A, Table 1 summarizes the land use, drainage area, population, population density and imperviousness of each basin used in the preproject simulation. Table 20 lists similar data used in the postproject simulation. Runoff and Transport blocks of the SWMM model were used for all preproject simulation and for postproject simulation of basins 1 through 9. For basin 10, the Runoff and Transport blocks were used for simulation of the high-level sewer system, and the Storage-Treatment block was used for simulation of the underflow tunnels.

Flows from high-level sewers are conveyed to the tunnel system through the dropshafts. A side weir structure at each dropshaft allows approximately twice the dry weather flow to

Table 19

Storms Used In System Evaluation

Date of Storm (Year 1977)	Mayfair Gage Precipitation, Inches	Duration, Hours	Storm Category
May 4-5	0.92	8	4
June 5	1.12	9	5
July 8	0.69	2	3
July 24	0.52	1	2
Aug. 8	1.94	9	9
Aug. 16	0.29	3	1
Aug. 31 Sept. 1	2.03	18	10
Sept.25	1.20	2	6

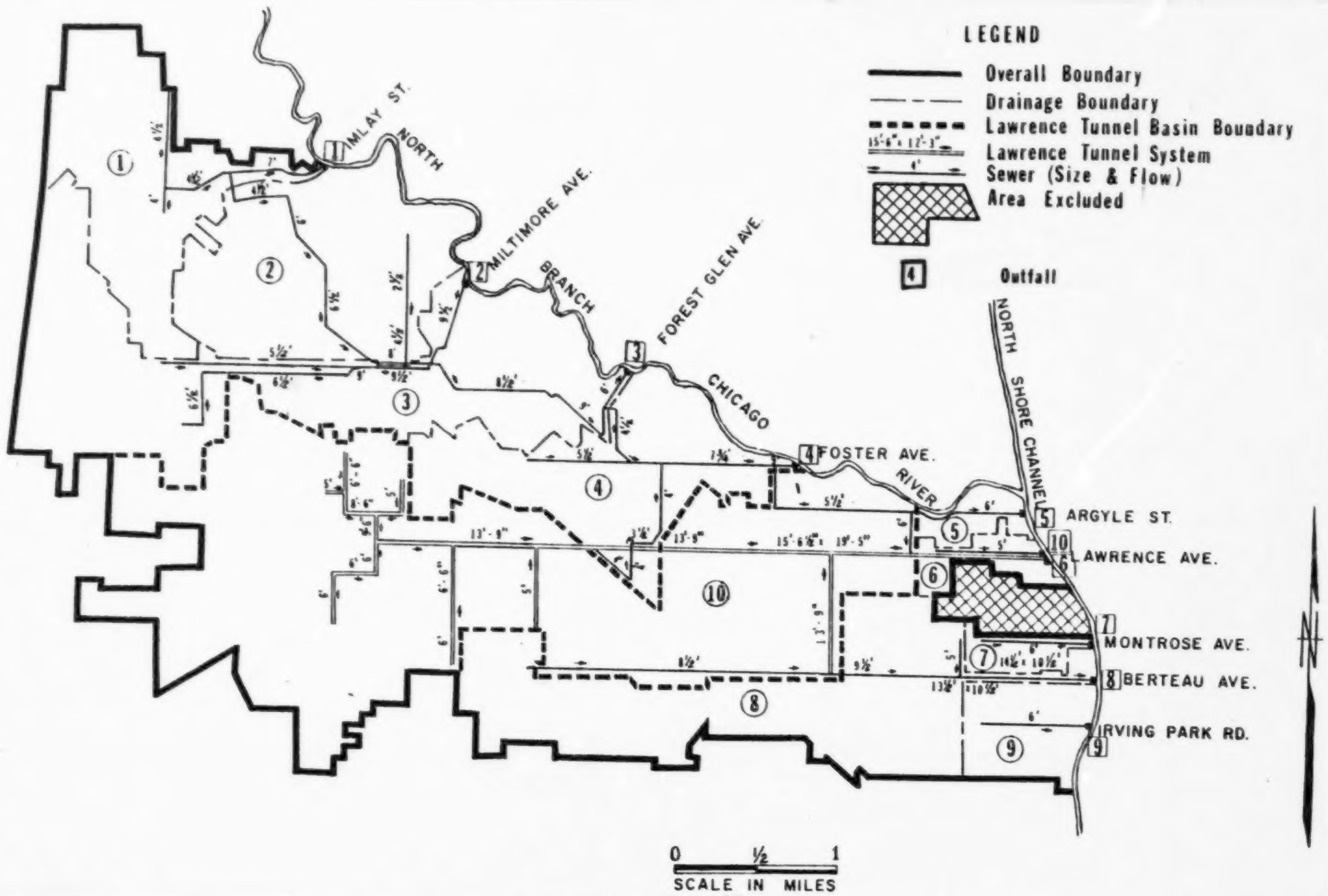
LEGEND
Overall Boundary
Drainage Boundary
Lawrence Tunnel Basin Boundary
Lawrence Tunnel System
Sewer (Size & Flow)
Area Excluded
Outfall
IMLAY ST.
NORTH
MILTIMORE AVE.
BRANCH
FOREST GLEN AVE.
CHICAGO
FOSTER AVE.
RIVER
NORTH SHORE CHANNEL
ARGYLE ST.
LAWRENCE AVE.
MONTROSE AVE.
BERTEAU AVE.
IRVING PARK RD.
15'-6" x 12'-3"
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Figure 12 Study Area Drainage Boundaries and Principal Sewers-Postproject Condition.

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Table 20

Land Use, Population, and Imperviousness of Study Area - Postproject Condition

Drainage Basin	Land Use										Total Land Area Acres	Population, Persons	Population Density, Persons/Acre	Average Imperviousness %
	Single Family Residential		Multi-Family Residential		Commercial		Industrial		Open Land Or Parks					
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%				
(1) Imlay St.	763	83.6	-	-	114	12.5	-	-	36	3.9	913	13,537	15	30
(2) Miltimore Ave	699	65.1	-	-	152	14.1	-	-	223	20.8	1,074	13,442	13	33
(3) Forest Glen Ave.	1,168	72.8	-	-	196	12.2	-	-	241	15.0	1,605	30,150	19	32
(4) Foster Ave.	491	63.1	-	-	64	8.2	45	5.8	178	22.9	778	14,448	19	33
(5) Argyle St.	62	52.5	21	17.8	15	12.7	-	-	20	17.0	118	5,517	47	32
(6) Lawrence Ave. (High Level)	40	33.9	18	15.2	37	31.4	-	-	23	19.5	118	4,453	38	45
(7) Montrose Ave.	73	65.8	-	-	17	15.3	-	-	21	18.9	111	5,118	46	44
(8) Berteau Ave.	941	71.7	-	-	191	14.6	19	1.4	161	12.3	1,312	36,474	28	39
(9) Irving Pk.Rd.	161	62.9	15	5.9	33	12.9	7	2.7	40	15.6	256	9,844	38	37
(10) Lawrence Ave. Tunnel System	2,337	65.2	76	2.1	589	16.4	16	0.5	565	15.8	3,583	85,153	24	35
Total Area * (3) thru (10)	5,273	66.9	130	1.61	1,142	14.5	87	1.1	1,249	15.9	7,881	191,157	24	35

*Imlay St. and Miltimore Ave. basins are excluded as they are not affected by the Tunnel System.

continue along the high-level sewer and the excess flow during storms spills into the tunnel system. This condition was modeled in the program by use of Type-18 flow dividers.

Flows were assumed to enter the tunnel with perfect mixing. There was no dewatering during storms. The tunnels and shafts have a storage capacity of approximately 4.9 million cubic feet (0.14 million cubic meters) represented as a reservoir in the model. The outfall was modeled by means of a fictitious weir. The actual overflow to the river occurs when the water level in outfall shaft exceeds the water surface in the North Branch of the Chicago River. The water surface elevation in the river varies from -2.0 feet Chicago City Datum (CCD) during dry weather to +6.5 CCD during very large storms. The weir crest was assumed at elevation +3.0 CCD, which is approximately the average river water surface elevation during storms. A very long weir was assumed so that when the tunnel fills up to elevation +3.0 CCD, all incoming flows would spill to the river.

Due to program limitations in the Storage-Treatment block, a minimum of 5 MGD (18.9 million liters per day) of inflow had to bypass the storage reservoir, and go directly to the treatment plant. This quantity was added manually to the captured flows if the tunnels were not full, and to the overflows if spillage occured. This 5 MGD (18.9 million liters per day) flow was assumed to have the same concentrations of BOD and Suspended Solids as the inflows to the Storage block.

For convenience, the starting time of each rainfall was set at the beginning of a clock hour, with insertion of some zero values for no rainfall periods. Five-minute intervals were used on all storms except the September 1st storm, for which ten-minute intervals were used due to its long duration.

Computer runs were made for the selected storms listed in Table 19 for each of the basins described above. The combined sewer flows along with the pounds of BOD and Suspended Solids spilled to the river were compiled from the computer outputs, and totals for preproject and postproject condition were computed.

To evaluate the effectiveness of the Lawrence Avenue Underflow Sewer System in reducing spillage of flows and pollution to the waterway, it was necessary to compute base line preproject overflow quantities for basin 10. This was obtained by subtracting overflow quantities from the seven high-level sewer outfalls (basins 3 through 9) for postproject runs from similar quantities from these basins for preproject runs. The only difference in the data for these two sets of computer runs is the absence of the area tributary to the Lawrence Avenue System from the latter (postproject) set of runs. Therefore, it can be assumed for the purpose of comparisons, that the difference in overflows between the two sets of runs would be the equivalent of preproject overflows from basin 10, which is the area directly served by the Lawrence Avenue System. The overflow quantities thus computed, along with the postproject overflow quantities directly obtained from the Storage-Treatment block are tabulated in Table 21 for the eight storms selected from 1977 precipitation data.

Since a continuous simulation was not feasible with the SWMM model, as explained earlier, the overflow data computed for the selected storms was then extrapolated to obtain annual quantities. The overflow quantities for each storm were multiplied by the yearly recurrence frequency (see Table 18) and then added together for all storms. The resulting quantities are representative of the yearly overflow quantities. This approach is considered reasonable, particularly as the figures are utilized for comparison purposes. The overflow quantities obtained in this manner for the year 1977, which was selected as a typically average hydrologic year, have been summarized in Table 22 for the drainage area directly served by the Lawrence Avenue System (basin 10).

The overflow summary for the overall drainage area affected by the Lawrence Avenue System is presented in Table 23 for the selected storms and in Table 24 for the year 1977. Preproject overflow figures are totals from the seven conventional sewer outfalls serving basins 3 through 9. Post-project overflow figures also include output from the tunnel outfall (basin 10), in addition to overflows from basins 3 through 9.

Precipitation for each storm has been included in Tables 21 and 23 for ready reference. Similarly, total hours of precipitation and yearly precipitation have been included in Tables 22 and 24. Percent reductions in spillage of flows, BOD and Suspended Solids are presented in each of the Tables 21 through 24.

C. DISCUSSION OF COMPUTER SIMULATION RESULTS

Table 21 shows that 5 out of the 8 storms analyzed are completely captured by the Lawrence Avenue System for its direct drainage area of 3,583 acres (1,451 hectares). The largest storm captured has a precipitation of over one inch (2.54 cm). The larger storms that overflow are partially captured in the percentages indicated on the Table. For the

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Table 21
Performance Comparison for Selected Storms - Preproject Vs. Postproject Drainage Area Directly Served by Lawrence Avenue System *

Date of Storm (1977)	Precipitation, Inches	Overflow to River						Reduction in Overflows due to Lawrence Ave.System (Percent)		
		Preproject			Postproject					
		Flow 1000 CF	B.O.D. LBS.	S.S. LBS.	Flow 1000 CF	B.O.D. LBS.	S.S. LBS.	Flow	B.O.D.	S.S.
May 4-May 5	0.92	3,310	14,800	25,800	0	0	0	100.0	100.0	100.0
Jun 5	1.12	4,120	10,800	31,500	0	0	0	100.0	100.0	100.0
Jul 8	0.69	2,760	13,300	46,100	0	0	0	100.0	100.0	100.0
Jul 24	0.52	1,920	10,000	35,800	0	0	0	100.0	100.0	100.0
Aug 8	1.94	8,760	13,400	14,700	3,860	6,150	5,480	55.9	54.1	62.7
Aug 16	0.29	910	4,940	14,300	0	0	0	100.0	100.0	100.0
Aug 31-Sep 1	2.03	8,370	17,200	34,000	3,470	12,000	24,400	58.5	30.2	28.2
Sep 25	1.20	6,020	13,400	12,600	1,120	2,590	2,330	81.4	80.7	81.5

* See Figure 12

Table 22

Performance Comparison for a Typical Year (1977)
Preproject Vs. Postproject
Drainage Area Directly Served by Lawrence Avenue System *

Hours of Precipitation		382
Total Precipitation, Inches		36.07
Preproject Overflows	Flow, 1000 CF	136,000
	B.O.D., LBS.	476,000
	S.S., LBS.	1,284,000
Postproject Overflows	Flow, 1000 CF	22,000
	B.O.D., LBS.	50,000
	S.S., LBS.	72,000
Reduction In Overflows Due To Lawrence Ave System	Flow	83.8%
	B.O.D.	89.5%
	S.S.	94.4%

* See Figure 12

Table 23
Performance Comparison for Selected Storms - Preproject Vs. Postproject Overall Drainage Area Affected by Lawrence Avenue System *

Date of Storm (1977)	Precipitation, Inches	Overflow to River						Reduction in Overflows due to Lawrence Ave. System (Percent)		
		Preproject			Postproject					
		Flow 1000 CF	B.O.D. LBS.	S.S. LBS.	Flow 1000 CF	B.O.D. LBS.	S.S. LBS.	Flow	B.O.D.	S.S.
May 4- May 5	0.92	9,290	34,900	64,300	5,980	20,100	38,500	35.6	42.4	40.1
Jun 5	1.12	11,500	26,200	77,000	7,380	15,400	45,500	35.8	41.2	40.9
Jul 8	0.69	7,600	31,300	115,000	4,840	18,000	68,900	36.3	42.5	40.1
Jul 24	0.52	5,300	23,800	86,500	3,380	13,800	50,700	36.2	42.0	41.4
Aug 8	1.94	23,700	28,900	30,500	18,800	21,700	21,300	20.7	24.9	30.2
Aug 16	0.29	2,580	12,200	35,200	1,670	7,260	20,900	35.3	40.5	40.6
Aug 31- Sep 1	2.03	23,000	39,500	83,200	18,100	34,300	73,600	21.3	13.2	11.5
Sep 25	1.20	16,000	29,100	28,200	11,100	18,300	17,900	30.6	37.1	36.5

* See Figures 5 and 12

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Table 24

Performance Comparison for a Typical Year (1977) Preproject Vs. Postproject Overall Drainage Area Affected by Lawrence Avenue System *

Hours of Precipitation		382
Total Precipitation, Inches		36.07
Preproject Overflows	Flow, 1000 CF	375,000
	B.O.D., LBS.	1,121,000
	S.S., LBS.	3,133,000
Postproject Overflows	Flow, 1000 CF	260,000
	B.O.D., LBS.	695,000
	S.S., LBS.	1,921,000
Reduction In Overflow due to Lawrence Ave. System	Flow	30.7%
	B.O.D.	37.9%
	S.S.	38.7%

* See Figures 5 and 12

September 25th storm it would be noticed that the percentage of BOD and Suspended Solids captured is about the same as the percentage of flow captured. On the other hand, for the September 1st storm, with a larger precipitation, the proportion of pollution captured is much lower. The former storm has a duration of only two hours, while the latter has a duration of 18 hours (see Table 19).The longer duration storm has lower concentration of pollutants towards the tail end of the hydrograph resulting in dilution of the captured flows. Consequently the proportion of pollutants captured is reduced.

Table 22 illustrates that the Lawrence Avenue Underflow Sewer System reduces the annual combined sewer overflows from its direct tributary area by 84 percent, and the annual spillage of BOD and Suspended Solids to waterway by 90 percent and 94 percent respectively. The major portion of the reduction in overflows comes from total capture of a large number of smaller storms as is evident from an examination of Table 21 along with Table 18 which gives the recurrence frequency of the various storms used in the study.

Table 23 and 24 give the reductions in overflows for the overall area of 7,881 acres (3,192 hectares) affected by the Lawrence Avenue System, for the listed storms and for the year 1977 respectively. The range of reduction in spillage of flows is from 21 to 36 percent, of BOD is from 13 to 43 percent and of Suspended Solids is from 12 to 41 percent. The yearly capture is 31 percent of overflow quantity, 38 percent of BOD and 39 percent of Suspended Solids.

As stated earlier, the annual quantities listed in Tables 22 and 24 were computed on a pro rata basis using the actual computed figures for various storms and the annual recurrence frequency of those storms. Therefore caution should be exercised in the use of these figures for other than the comparisons made in this report.

D. GROUNDWATER MONITORING

As the Lawrence Avenue Underflow Tunnel System is located about 250 feet (76 m) below the ground level in the rock strata and the tunnel system will be subjected to hydrostatic pressures of the order of 250 feet (76 m) it is necessary to assess the effect of the tunnel system on the surrounding aquifer and particularly on the Wilson Avenue Water Tunnel which crosses the tunnel system at Harding Avenue.

Three monitoring wells were constructed in the south parkway of West Wilson Avenue west of North Harding Avenue. The

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general location of the monitoring wells is marked on Figure 4, a plan view is shown in Figure 13 and a vertical section along the wells looking north is shown in Figure 14. Since the monitoring wells were considered more or less permanent appurtenances for the Lawrence Avenue Sewer System, the City's Department of Water had recommended motor-operated sampling equipment and a relatively reliable method of determining water depths in the wells. The equipment used in the monitoring wells consists of:

1. A small submersible electrical pump, about 10 GPM (38 liters/min.),to fit inside the well casing is used in each monitoring well. The wells have a 12-3/4 inch (32.4 cm) O.D. outer casings and 6-5/8 inch (16.8 cm) O.D. inner casings. The discharge pipe is 1¼ inch (3.2 cm) in diameter.

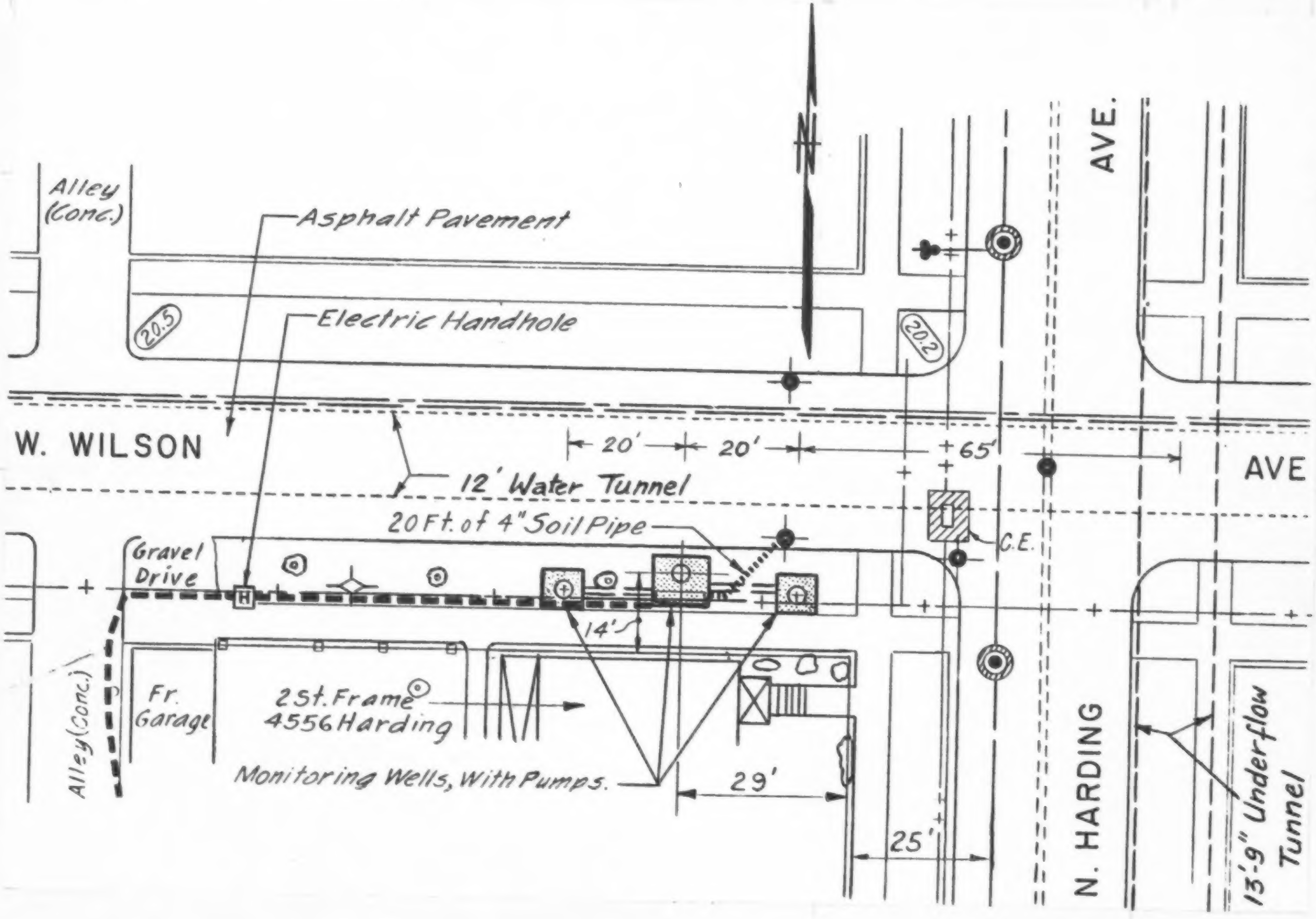
2. Water elevation equipment includes a small air compressor, a depth gage for direct readings and a continuous water level recording instrument with a 31 day recording chart.

All instrumentation is enclosed in a protective metal housing with locking arrangements. Electric power is supplied by connection to the Commonwealth Edison Company line.

The wells are 20 feet (6.1 m) apart from center to center. The approximate ground elevation at the wells is +20.0. Elevation of the well bottom is -159.3 for the east well, -208.7 for the center well and -121.8 for the west well. The outer casing extends to a depth approximately 74 feet (22.6 m) below grade to bed rock. A 10 inch (25.4 cm) hole extends to the bottom of each well and contains the inner casing to within 20 feet (6.1 m) of the bottom (see Figure 14).

These wells were drilled before the tunnel was operational to establish a basis of comparison with the monitoring data obtained after the sewer tunnels are put into operation. Personnel from the Water Surveillance Section of the City's Department of Water collected the data on a regular basis at 2 to 4 weeks intervals. The data consisted of readings of water depths in the wells and samples from each well which were subsequently analyzed at the City's Water Purification Laboratory.

The preproject monitoring program was carried on from December 1969 through April 1976 with some interruptions during periods when the monitoring equipment needed servicing or repairs.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2 St. Frame
4556 Harding
Alley (Conc.)
Monitoring Wells, With Pumps.
29'
25'
N. HARDING
13'-9" Underflow Tunnel

Figure 13 Site Plan of Monitoring Wells

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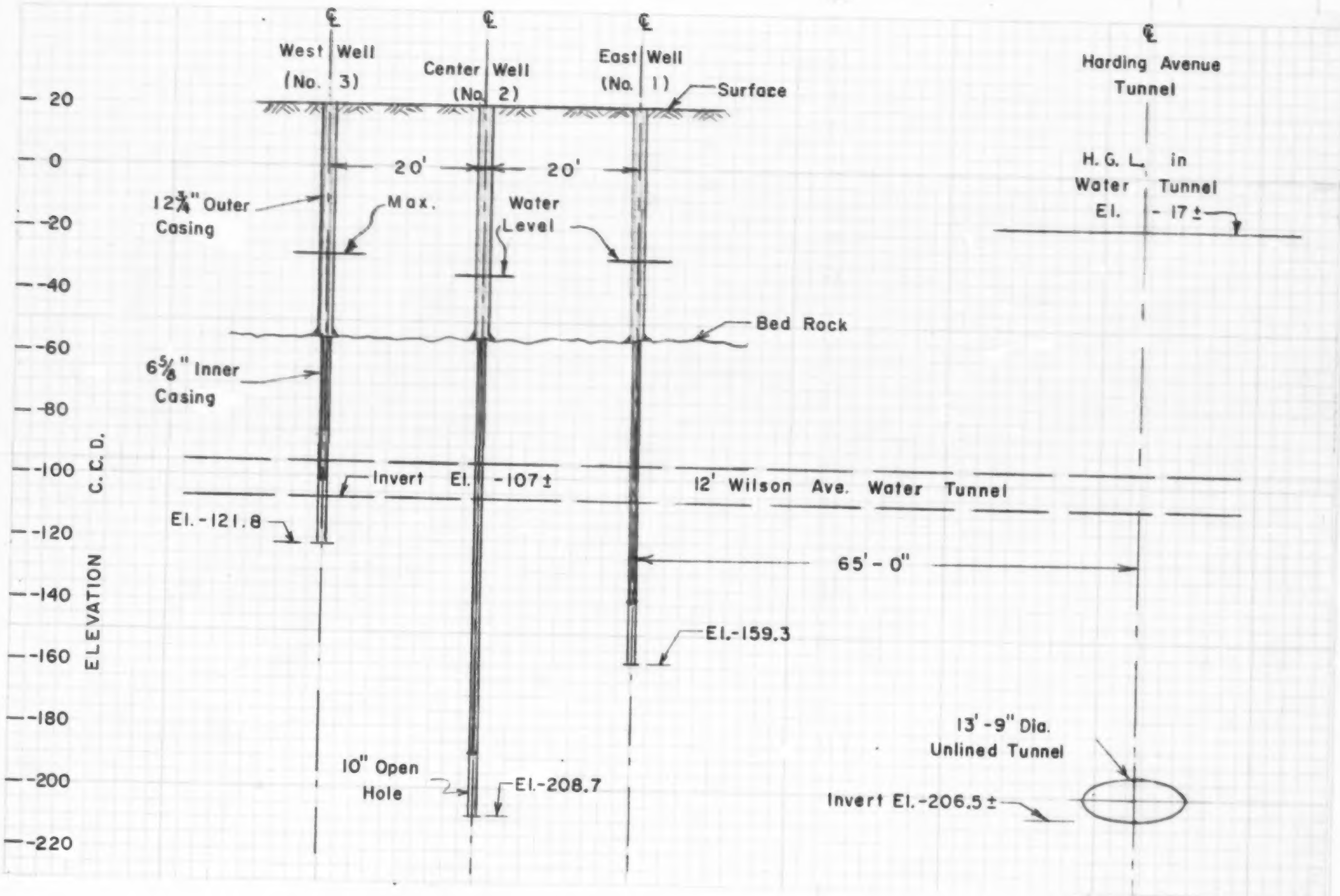
℄
West Well (No. 3)
℄
Center Well (No. 2)
℄
East Well (No. 1)
Surface
℄
Harding Avenue Tunnel
H. G. L. in Water Tunnel El. - 17 ±
20'
20'
12¾" Outer Casing
Max.
Water Level
Bed Rock
6⅝" Inner Casing
Invert El. -107 ±
12' Wilson Ave. Water Tunnel
El. -121.8
65' - 0"
El. -159.3
13'-9" Dia. Unlined Tunnel
10" Open Hole
El. -208.7
Invert El. -206.5 ±
ELEVATION C.C.D.
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220

Figure 14 Details of Monitoring Wells

Due to delays in completion of the project and the need for repairs to the monitoring equipment, no data was collected from May 1976 through April 1981. As stated earlier, the tunnel system is still not in complete operation. However, the tunnels do collect the combined sewage during storms and surcharge to river level. The system is partially dewatered following the storm just to lower the hydrostatic pressure on the tunnel system. In normal operation the tunnels would be completely emptied. Therefore, any sampling at this time. while not representative of the normal operation,is on the conservative side. The postproject sampling was carried on during May through August 1981.

A sample of the field notes is shown in Table 25. Samples of chemical and bacteriological analysis reports are shown in the Tables 26 and 27 respectively. The data is too numerous to include in this report. Summaries of chemical analysis results from the three Monitoring Wells are given in Tables 28, 29 and 30. The tables list the maximum and minimum values of each constituent found in the entire data set for preproject and postproject conditions. Sampling periods and number of samples in the data set are also given in the tables. Similar tabulation of bacteriological analysis results from the three monitoring wells are given in Tables 31, 32 and 33 respectively. Postproject data was not available from Monitoring Well No. 1 (East Well) as it was out of service. However, the data from the other two wells is indicative of the general conditions in the aquifer during the postproject sampling period.

Comparison of the preproject and postproject data indicates no change in the quality of groundwater that could be attributed to pollution from combined sewage. Most of the constituents in Table 29 and 30 show no change. Turbidity and Total Iron are higher for Well No. 2 and Hardness and Total Iron are higher for Well No. 3. None of these constituents could be related to pollution from the combined sewage.

As for the bacteriological quality of the groundwater, Table 33 shows all constituents for postproject conditions are within the range of the values observed during preproject conditions for the Well No. 3. Table 32 shows the bacterial count is somewhat higher for Well No. 2. However, the number of bacteria are in the same order of magnitude and could not be considered large enough to point out a change in the quality of groundwater, particularly in view of the remaining data which shows absolutely no Coliforms, Fecal Coliforms or Fecal Streptococci.

For preproject conditions the range of groundwater levels

Table 25

Monitoring Wells - Sample Field Notes

WATER PURIFICATION DIVISION
Water Quality Surveillance Section
City of Chicago
1000 East Ohio Street
Chicago, Illinois 60611

LAWRENCE AVENUE DEEP TUNNEL MONITORING WELL
SAMPLING CARD

SAMPLED BY P. Vinciotore

DATE Nov. 4 1971

SAMPLING DATA	WELL NUMBER 1	WELL NUMBER 2	WELL NUMBER 3
Time pump turned on	11:04 am	11:04 am	11:14 am
Time pump sampled	11:09 am	11:09 am	11:19 am
Time pump turned off	11:14 "	11:34 "	11:32 "
Well height at beginning	42 (-113.5)	90 (-[illegible])	57 (-[illegible])
Well height at sampling	30	75	57
Well height at end	12'	16	34
Temperature °F	51	52	52

Remarks:

Reproduced from best available copy.

Table 26

Monitoring Wells - Sample Chemistry Laboratory Report

CITY OF CHICAGO, DEPARTMENT OF WATER & SEWERS, BUREAU OF WATER
WATER PURIFICATION DIVISION
WATER PURIFICATION LABORATORY
CHEMICAL SECTION

WATER QUALITY REPORT

DATE: May 16, 1973

Date Collected May 11, 1973

Collected by RSP

Date Rec'd in Lab. May 11, 1973

Submitted by Monitoring Wells

Analyst STAFF

Location Wilson & Harding Avenues

Investigator's Remarks

Sample Identity	Q281 3Q264	Q282 3Q365	Q283 3Q266	
Sample Source	Pump No. 1	Pump No. 2	Pump No. 3	
Time Collected	11:35 AM	11:45 AM	11:56 AM	
Chlorine Residual	nil	nil	nil	
Fluoride	2.1	0.46	1.00	
* Turbidity	50	4.2	3.6	
* pH	9.13	8.58	9.00	
* Odor, Straight	4DME	3DM	5DME	
* Odor, Dechlorinated				
Chlorides	15.2	14.5	19.0	
Hardness	16	70	10	
Alkalinity, Phenol	20	3	10	
Alkalinity, M-P	291	80	125	
Ammonia Nitrogen	0.01	0.02	0.02	
Lead	0.013	ND	ND	
Phosphates, Total	0.12	0.15	0.15	
Sulfates	19.5	37.1	27.1	
Phenol	0.004	0.002	ND	
MBAS (Detergent)				
Iron, Total				
* Mercury (ppb)	< 0.1	< 0.1	< 0.1	
COD	5.0	3.0	4.0	
Temperature °F	52	54	54	

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Table 27

Monitoring Wells - Sample Bacteriology Laboratory Report

Department of Water and Sewers
Bureau of Water
Water Purification Division
WATER QUALITY SURVEILLANCE SECTION

BACTERIOLOGICAL ANALYSES OF SAMPLES OF WATER COLLECTED FROM

MONITORING WELL No. 2

HARDING AND WILSON AVES.

By R. Parker

Date

WQSS NO.	DATE	LOCATION & SOURCE	TIME COLL-ECTED	RES. cl_2 PPM	BACT. /ml 35°C	TOTAL COLI M F	TOTAL COLI M P N	FECAL COLI.	FECAL STREP.	REMARKS
Q 20	1-11-74		12:10P		1	0	0	0	0	
Q 60	1-25-74		10:40A		0	0	0	0	0	
Q 93	2-8 -74		12:40P		10	0	0	0	0	
Q 135	3-1 -74		10:55A		40	0	0	0	0	
Q 159	3-11-74		11:20A		13	0	0	0	0	
Q 196	3-25-74		10:30A		210	0	0	0	0	
Q 252	4-8 -74		12:55P		3	0	0	0	0	
Q 282	4-22-74		11:35A		0	1	2.2	0	0	
Q 365	5-7 -74		11:25A		54	0	9.2	0	1	
Q 416	5-20-74		11:00A		24	0	2.2	0	0	
Q 468	6-3 -74		11:55A		38	0	2.2	0	0	
Q 664	7-8 -74		11:30A		2	0	0	0	0	
Q 716	7-23-74		11:00A		3	0	0	0	0	
Q 779	8-5 -74		12:20P		4	0	2.2	0	0	
Q 839	8-19-74		11:50A		0	0	0	0	0	
Q 924	9-19-74		11:45A		14	0	0	0	0	
Q 955	10-3-74		11:00A		3	0	0	0	0	
Q 997	10-24-74		11:15A		26	0	0	0	0	
Q1064	11-14-74		10:50A		5	0	0	0	0	
Q1114	11-25-74		12:00		0	0	0	0	0	
Q1174	12-12-74		10:55A		0	0	0	0	0	

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Table 28

Summary of Chemical Analysis Results
Monitoring Well No. 1 (East Well)

	Preproject	Postproject
Sampling Period	Dec.'69-Apr.'76	None
Number of Samples	87	

Constituents	Range of Values	
	Preproject Data	Postproject Data
COD, Mg/L	0.85 - 52.4	None as Well Out of Service
Ammonia Nitrogen,Mg/L	0.01 - 0.8	
Phosphates, Mg/L	0.01 - 3.25	
Chlorides, Mg/L	11.8 - 44	
Fluoride, Mg/L	0.74 - 2.64	
Turbidity (JTU)	0.6 - 150	
pH	8.2 - 9.85	
Odor, Straight (TON)	1 - 25	
Hardness (CaCo3, Mg/L	9 - 76	
Alkalinity (Phth),Mg/L	0 - 40	
Alkalinity(Total),Mg/L	99 - 319	
Total Iron, μg/L	5.9 - 10000	

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Table 29

Summary of Chemical Analysis Results
Monitoring Well No. 2 (Center Well)

	Preproject	Postproject
Sampling Period	Dec.'69-Apr.'76	May'81-Sept.'81
Number of Samples	114	7

6-1/2"

Constituents	Range of Values	
	Preproject Data	Postproject Data
COD, Mg/L	0.85 - 249.4	1.7 - 10.6
Ammonia Nitrogen,Mg/L	0.01 - 0.9	0.02- 0.14
Phosphates, Mg/L	0.01 - 0.45	< 0.01- 0.06
Chlorides, Mg/L	8.9 - 30	13.3 - 18.5
Fluoride, Mg/L	0.23 - 1.21	0.23- 0.46
Turbidity (JTU)	0.4 - 70	0.95- 250
pH	7.67 - 11.48	8.5 - 9.8
Odor,Straight (TON)	1 - 10	1 - 3
Hardness (CaCo3),Mg/L	10 - 86	4 - 80
Alkalinity(Phth),Mg/L	0 - 10	4 - 15
Alkalinity(Total),Mg/L	40 - 123	47 - 123
Total Iron, µg/L	0.15 - 2500	2150 - 30000

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Table 30

Summary of Chemical Analysis Results
Monitoring Well No. 3 (West Well)

	Preproject	Postproject
Sampling Period	Dec.'69-Apr.'76	May'81-Sept.'81
Number of Samples	114	5

Constituents	Range of Values	
	Preproject Data	Postproject Data
COD, Mg/L	0.9 - 155	6.3 - 11.8
Ammonia Nitrogen,Mg/L	0.01 - 0.9	0.01 - 0.1
Phosphates, Mg/L	0.01 - 0.8	< 0.01 - 0.56
Chlorides, Mg/L	2 - 19	12.1 - 24.1
Fluoride, Mg/L	0.49 - 2.0	0.27 - 1.1
Turbidity (JTU)	1.0 - 200	0.55 - 230
pH	7.95 - 10.17	8.3 - 9.4
Odor, Straight (TON)	2 - 10	1 - 3
Hardness (CaCo3) Mg/L	4 - 36	4 - 80
Alkalinity(Phth),Mg/L	0 - 15	0 - 17
Alkalinity(Total),Mg/L	71 - 106	112 - 134
Total Iron, µg/L	0.18 - 8000	1800 - 19000

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Table 31

Summary of Bacteriological Analysis Results
Monitoring Well No. 1 (East Well)

	Preproject	Postproject
Sampling Period	Jun '71 - Apr'76	None
Number of Samples	26	

Constituents	Range of Values	
	Preproject Data	Postproject Data
Temperature, °C	10 - 15.6	None as
Bacteria/ml (35°C)	0 - 730	Well out
Total Coliform (MF) Colonies/100 ml	0	of Service
Total Coliform MPN/100 ml	0 - 24	
Fecal Coli, Colonies/100 ml	0	
Fecal Strep, Colonies/100 ml	0 - 78 *	

* Only one sample showed Fecal Strep

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Table 32

Summary of Bacteriological Analysis Results
Monitoring Well No. 2 (Center Well)

	Preproject	Postproject
Sampling Period	Jun'71-Apr'76	May '81 - Sep '81
Number of Samples	56	7

Constituents	Range of Values	
	Preproject Data	Postproject Data
Temperature, ^{o}C	10 - 13.3	11
Bacteria/ml ($35^{o}C$)	0 - 1400	0 - 2100
Total Coliform (MF) Colonies/100 ml	0 - 19	0
Total Coliform, MPN/100 ml	0 - 35	0
Fecal Coli., Colonies/100 ml	0 - 94	0
Fecal Strep., Colonies/100 ml	0 - TNC *	0

* Too Numerous to Count

Table 33

Summary of Bacteriological Analysis Results
Monitoring Well No. 3 (West Well)

	Preproject	Postproject
Sampling Period	Jun '71 - Apr'76	May '81-Sept '81
Number of Samples	51	5

Constituents	Range of Values	
	Preproject Data	Postproject Data
Temperature, °C	10 - 13.3	11
Bacteria/ml (35°C)	0 - TNC *	2 - 510
Total Coliform (MF) Colonies/100 ml	0	0
Total Coliform MPN/100 ml	0	0
Fecal Coli., Colonies/100 ml	0	0
Fecal Strep., Colonies/100 ml	0 - 2	0

* Too Numerous to Count

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observed was from El. -149.5 (CCD) to El. -29.5 for Well No. 1, from El. -134.7 to El. -34.7 for Well No. 2 and from El. -84.8 to El. -27.8 for Well No. 3. The approximate average groundwater level for the entire monitoring period was about El.-120 for Wells 1 and 2 and El. -50 for Well No. 3. Only one reading was available for postproject condition showing Elevations -140.3, -152.7 and -97.8 for water levels in Wells No. 1, 2 and 3 respectively. Maximum recorded water levels in the monitoring wells and approximate hydraulic grade line in the Wilson Avenue Water Tunnel are indicated in Figure 14. As the HGL in the water tunnel is always higher than the piezometric level in the surrounding aquifer there is no chance of infiltration into the tunnel and the tunnel water quality is not affected by the surrounding aquifer.

In conclusion, it can be stated on the basis of the groundwater monitoring that neither the underground aquifer nor the Wilson Avenue Water Tunnel has been found to have any adverse water quality effects due to the construction of the Lawrence Avenue Underflow Tunnel System.

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SECTION VII

OPERATIONAL EXPERIENCE AND RECOMMENDED IMPROVEMENTS

As described in Section V-A, equipment in the pumping station had been severely damaged by falling ice, although the pumps were not harmed. Pumping therefore temporarily had to be discontinued pending repairs. As a result information on actual storm events, such as volumes overflowing, volumes pumped to the interceptor, actual dewatering times, etc. could not be gathered for mass balance computations on the system. Also, before any meaningful samples of the flows to the river and interceptor could be taken, the tunnel system had to be dewatered and the residual solids had to be removed. In the absence of the dewatering capability the quality sampling could not be done to provide information for the computation of pollutional loads caused by actual storms and intercepted by the Lawrence Avenue System.

Since the Lawrence Avenue Pumping Station was the first of its kind to be built, it suffered a number of setbacks during various stages of its construction. These have been covered in sufficient details in Section V-A. As of the date of this report, the pumping station could not be put to a completely automatic mode of operation, as planned and designed. Therefore not much can be stated here about operational experience in that mode.

The pumps have been operated manually on an intermittent basis for approximately a year, sometimes to dewater the tunnels completely and other times to lower the water level in the shafts. After the problems involving leakages in the power cables and junction boxes were solved for the pumps, three pumps have been in place and functioning satisfactorily, in spite of remaining under a large head of water for more extended periods than would be encountered in normal operation.

Although the Lawrence Avenue Sewer System with its related pumping station is not yet completely operational, much knowledge has been gained from it. As a result, the Nashville Avenue Sewer System, which is basically the same, has been "on line" since October 1, 1980. Since that time, observation of both stations has given insight into some ways in which future pumping stations of this type can be improved.

Recommended improvements are: use of float valves to control pump operation at critical elevations; simplification of the control panels, meanwhile controlling and monitoring the same functions as currently; more positive anchorage of equipment to the shaft walls, and use of stronger elements; elimination of the elevator; installation of a crane girder to install and remove the pumps and other equipment from the shaft and to lower workers into the shaft; installation of a reinforced fabric type of cover on the top of the main shaft during cold weather, with provisions to fasten the cover to the shaft wall, thus minimizing freezing of moisture on the shaft walls; improvement of scales on recorders to make them more legible, and expanding the scales so that the functions they monitor cover the full range of the recorder; permitting optional use of precast vertical sections in dropshaft construction; installation of diaphragm-type louvers in the air vents of dropshafts to minimize escape of objectionable odors;and very significantly in new designs, obtaining the input of operations personnel handling such pumping stations.

In order to document systematic procedures, an Operations and Maintenance Manual should be prepared for each pumping station. Maintenance contracts with suppliers of special equipment should be a requirement. Other necessary actions are: frequent emptying of debris baskets and cleansing of equipment in the shaft and outfall structures; periodic inspections for closure of tide gates; and separate electrical metering for the pumps to obtain possible lower electrical rates and to document pump operational costs.

Throughout the operational history of pumping stations of this type, systematic documentation of problems should be made by the operating personnel, along with suggested methods of correction. Also, a vehicle of communication should be established for conveying this information on a periodic basis for insertion into a folder for future design.

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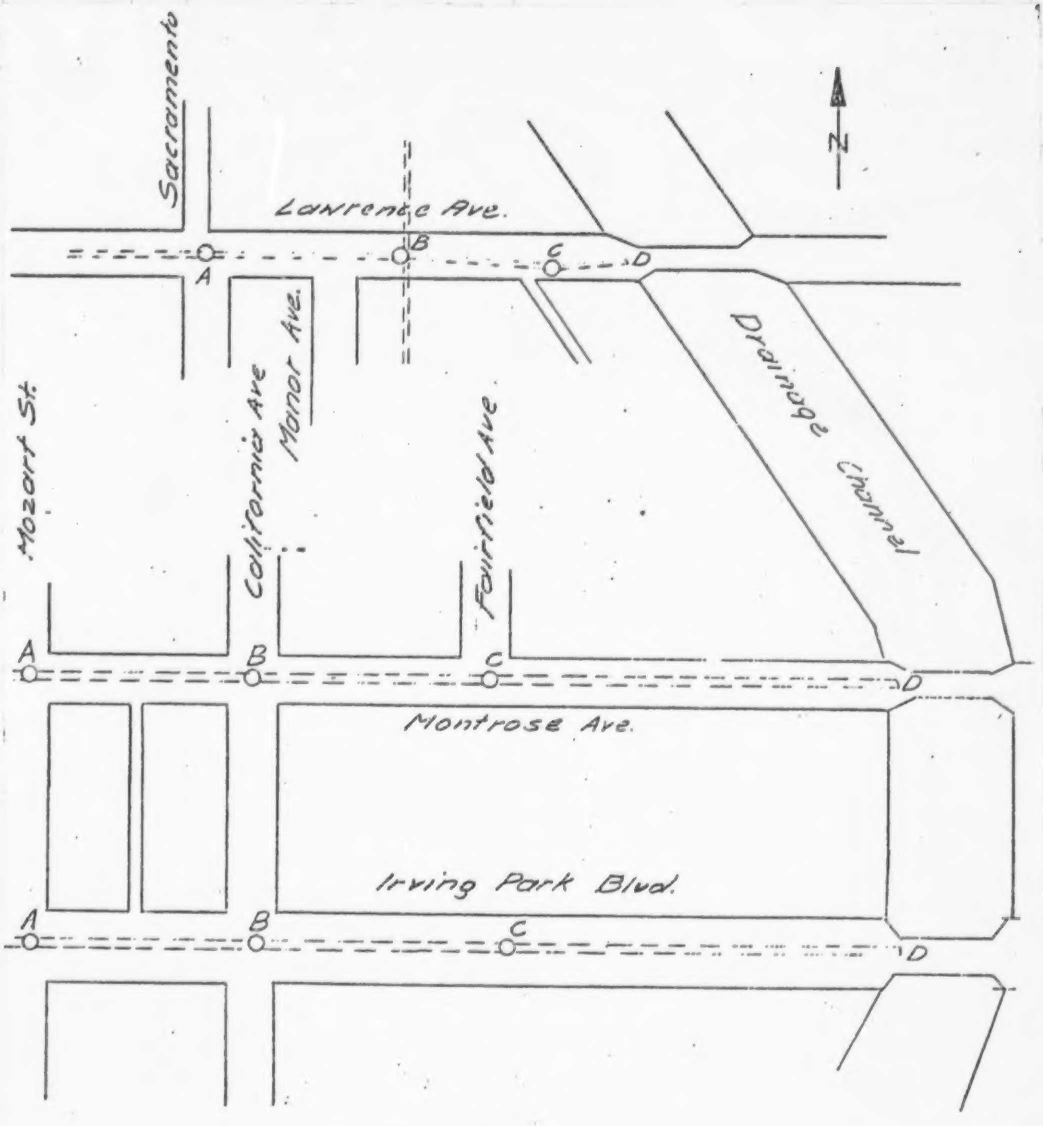
APPENDIX A

MEASURED DATA USED IN COMPUTER CALIBRATION


N
Sacramento
Lawrence Ave.
A
B
C
D
Manor Ave.
Drainage Channel
Mozart St.
California Ave
Fairfield Ave
A
B
C
D
Montrose Ave.
Irving Park Blvd.
A
B
C
D

A. Liquid Level Measured, Floats Dropped
B. Floats Timed, Sample Taken (Total)
C. Same as A
D. Same as B (Overflow)

LOCATION MAP

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TOTAL POINT B SAMPLE SUSPENDED SOLIDS 7-23-75 LAWRENCE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
9-45	65.070	221.00						8-45	246.0
10- 0	58.667	123.00	61.868	15.00	174.53	58214.21	606.39		
10-15	46.744	56.00	52.705	15.00	93.28	26507.13	276.11		
10-30	37.114	122.00	41.929	15.00	85.21	19261.16	200.63		
10-45	28.015	82.00	32.564	15.00	104.79	18397.42	191.63		
11-15	17.032	54.00	22.523	30.00	71.41	8671.43	180.65		
11-45	10.681	65.00	13.856	30.00	58.23	4350.58	90.63		
						TOTAL=	1546.08		

UVERFLOW PCINT D SAMPLE SUSPENDED SOLIDS 7-23-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
9-45	33.636	276.00						8-45	5.0
10- 0	38.441	99.00	36.038	15.00	181.60	35282.42	367.52	12-10	76.0
10-15	37.258	76.00	37.849	15.00	87.67	17891.01	186.36		
10-30	44.842	86.00	41.050	15.00	81.46	18027.81	187.78		
10-45	17.238	122.00	31.040	15.00	95.99	16063.91	167.33		
11-15	7.154	49.00	12.196	30.00	100.58	6613.72	137.78		
11-45	1.097	22.00	4.125	30.00	45.41	1009.96	21.04		
						TOTAL=	1067.83	DIVERTED=	478.24

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TOTAL POINT B SAMPLE BOD 7-23-75 LAWRENCE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
9-45	65.070	139.00							
10- 0	58.667	102.00	61.868	15.00	121.45	40510.61	421.98	8-45	158.0
10-15	46.744	101.00	52.705	15.00	101.55	28856.22	300.58		
10-30	37.114	79.20	41.929	15.00	91.35	20649.36	215.09		
10-45	28.015	85.80	32.564	15.00	82.03	14402.57	150.02		
11-15	17.032	84.20	22.523	30.00	85.19	10344.88	215.51		
11-45	10.681	77.60	13.856	30.00	81.65	6099.84	127.08		
						TOTAL=	1430.29		

OVERFLOW POINT D SAMPLE BOD 7-23-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
9-45	33.636	109.00							
10- 0	38.441	99.00	36.038	15.00	103.66	20141.01	209.80	8-45	72.6
10-15	37.258	79.60	37.849	15.00	89.45	18252.55	190.13	12-10	82.5
10-30	44.842	109.00	41.050	15.00	95.65	21169.45	220.51		
10-45	17.238	102.00	31.040	15.00	107.05	17914.69	186.61		
11-15	7.154	95.70	12.196	30.00	100.15	6584.96	137.18		
11-45	1.097	79.20	4.125	30.00	93.50	2079.66	43.32		
						TOTAL=	987.57	DIVERTED=	442.72

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TOTAL POINT B SAMPLE  SUSPENDED SOLIDS  7-23-75  MONTROSE
-----------------------------------------------------------------------------------------------------------
TIME OF  I C(CFS)  I SAMPLE  I   QAVE  I TIME INT I SAMPLE  I    SAMPLE  I SAMPLE  I   GRAB SAMPLE
MST      I         I (MG/L)  I  (CFS)  I  (MIN)   I WT AVE  I   LBS/DAY  I  LBS    I  TIME      MG/L
-----------------------------------------------------------------------------------------------------------
  9-30   I 19.143  I 303.00  I         I          I         I            I         I  8-40     331.0
                             I 22.938  I   15.00  I 266.87  I  33002.07  I 343.77  I
  9-45   I 26.734  I 241.00  I         I          I         I            I         I
                             I 29.143  I   15.00  I 198.77  I  31230.59  I 325.31  I
 10- 0   I 31.553  I 163.00  I         I          I         I            I         I
                             I 30.560  I   15.00  I 151.38  I  24941.68  I 259.80  I
 10-15   I 29.567  I 139.00  I         I          I         I            I         I
                             I 28.209  I   15.00  I 130.43  I  19836.21  I 206.62  I
 10-30   I 26.852  I 121.00  I         I          I         I            I         I
                             I 23.678  I   15.00  I 109.74  I  14008.63  I 145.92  I
 10-45   I 20.504  I  95.00  I         I          I         I            I         I
-----------------------------------------------------------------------------------------------------------
                                                                  TOTAL=    1281.44  I
-----------------------------------------------------------------------------------------------------------
OVERFLOW POINT D SAMPLE  SUSPENDED SOLIDS  7-23-75                                   I  RIVER SAMPLE
                                                                                     I  TIME      MG/L
-----------------------------------------------------------------------------------------------------------
  9-30   I  7.816  I 234.00  I         I          I         I            I         I
                             I  9.425  I   15.00  I 272.04  I  13823.01  I 143.98  I  8-40      38.0
  9-45   I 11.034  I 299.00  I         I          I         I            I         I
                             I 12.064  I   30.00  I 296.28  I  19269.87  I 401.45  I  11-03     65.0
 10-15   I 13.094  I 294.00  I         I          I         I            I         I
                             I  9.414  I   15.00  I 272.37  I  13823.58  I 143.99  I
 10-30   I  5.734  I 223.00  I         I          I         I            I         I
                             I  5.256  I   15.00  I 157.53  I   4464.62  I  46.50  I
 10-45   I  4.780  I  79.00  I         I          I         I            I         I
-----------------------------------------------------------------------------------------------------------
                                                                  TOTAL=     735.94  I  DIVERTED= 545.50
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BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUS TRATIONS

3/8"

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TOTAL POINT B SAMPLE  BOD  7-23-75  MONTROSE

--------------------------------------------------------------------------------------------------------------
TIME OF I C(CFS)  I SAMPLE  I  QAVE  I TIME INT I SAMPLE  I   SAMPLE   I SAMPLE I   GRAB SAMPLE
  PST   I         I (MG/L)  I (CFS)  I  (MIN)   I WT AVE  I  LBS/DAY   I  LBS   I TIME       MG/L
--------------------------------------------------------------------------------------------------------------
  9-30  I 19.143  I 191.00  I        I          I         I            I        I  8-40      177.0
  9-45  I 26.734  I 135.00  I 22.938 I  15.00   I 158.36  I  19584.17  I 204.00 I
 10- 0  I 31.553  I 122.00  I 29.143 I  15.00   I 127.96  I  20104.82  I 209.42 I
 10-15  I 29.567  I  72.60  I 30.560 I  15.00   I  98.10  I  16162.52  I 168.35 I
 10-30  I 26.852  I  82.50  I 28.209 I  15.00   I  77.31  I  11757.54  I 122.47 I
 10-45  I 20.504  I  75.90  I 23.678 I  15.00   I  79.64  I  10166.33  I 105.89 I
--------------------------------------------------------------------------------------------------------------
                                                           TOTAL=        810.16 I
--------------------------------------------------------------------------------------------------------------
OVERFLOW POINT D SAMPLE BOD  7-23-75                                             I   RIVER SAMPLE
                                                                                 I TIME       MG/L
--------------------------------------------------------------------------------------------------------------
  9-30  I  7.816  I 139.00  I        I          I         I            I        I  8-40       39.6
  9-45  I 11.034  I 177.00  I  9.425 I  15.00   I 161.24  I   8192.93  I  85.34 I 11-03       79.2
 10-15  I 13.094  I 139.00  I 12.064 I  30.00   I 156.37  I  10170.49  I 211.88 I
 10-30  I  5.734  I 132.00  I  9.414 I  15.00   I 136.86  I   6946.27  I  72.35 I
 10-45  I  4.780  I  46.20  I  5.256 I  15.00   I  92.99  I   2635.49  I  27.45 I
--------------------------------------------------------------------------------------------------------------
                                                           TOTAL=        397.03 I DIVERTED= 413.12
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BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

PAGE NUMBER

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 7-23-75 IRVING

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
10- 0	29.606	186.00							
10-15	33.081	153.00	31.343	15.00	168.58	28486.74	296.73		
10-30	27.435	261.00	30.257	15.00	201.96	32944.68	343.17		
10-45	21.754	95.00	24.594	15.00	187.58	24872.17	259.08		
11- 0	17.312	80.00	19.533	15.00	88.35	9303.89	96.91		
11-15	9.467	185.00	13.389	15.00	117.11	8454.16	88.06		
11-30	6.319	96.00	7.892	15.00	149.37	6356.13	66.20		
						TOTAL=	1150.18		

OVERFLOW POINT D SAMPLE SUSPENDED SOLIDS 7-23-75

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
10- 0	18.558	197.00							
10-30	8.139	234.00	13.348	30.00	208.28	14988.41	312.25	9-35	46.
10-45	4.248	125.00	6.193	15.00	196.61	6565.05	68.38		
11-15	0.066	67.00	2.157	30.00	124.11	1443.25	30.06		
11-30	0.023	58.00	0.044	15.00	64.67	15.51	0.16		
						TOTAL=	410.87	DIVERTED= 739.31	

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BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

EPA-287 (Cin.)
(4-76)

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BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

PAGE NUMBER

EPA-287 (Cin.)
(4-76)

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TOTAL POINT B SAMPLE  BOD  7-23-75  IRVING
--------------------------------------------------------------------------------------------------------
TIME OF  I C(CFS)  I SAMPLE  I  QAVE  I TIME INT I SAMPLE  I  SAMPLE   I SAMPLE I   GRAB SAMPLE
  MST    I         I (MG/L)  I (CFS)  I  (MIN)   I WT AVE  I  LBS/DAY  I  LBS   I  TIME      MG/L
--------------------------------------------------------------------------------------------------------
 10- 0   I 29.606  I  92.40  I        I          I         I           I        I
                             I 31.343 I   15.00  I  92.39  I  15613.31 I 162.63 I
 10-15   I 33.081  I  92.40  I        I          I         I           I        I
                             I 30.257 I   15.00  I  91.67  I  14954.25 I 155.77 I
 10-30   I 27.435  I  90.80  I        I          I         I           I        I
                             I 24.594 I   15.00  I  85.66  I  11359.04 I 118.32 I
 10-45   I 21.754  I  79.20  I        I          I         I           I        I
                             I 19.533 I   15.00  I  73.35  I   7724.08 I  80.45 I
 11- 0   I 17.312  I  66.00  I        I          I         I           I        I
                             I 13.389 I   15.00  I  81.20  I   5861.43 I  61.05 I
 11-15   I  9.467  I 109.00  I        I          I         I           I        I
                             I  7.892 I   15.00  I 102.35  I   4355.39 I  45.36 I
 11-30   I  6.319  I  92.40  I        I          I         I           I        I
--------------------------------------------------------------------------------------------------------
                                                              TOTAL=     623.61 I
--------------------------------------------------------------------------------------------------------
OVERFLOW POINT D SAMPLE  BOD  7-23-75                                           I   RIVER SAMPLE
                                                                                I  TIME      MG/L
--------------------------------------------------------------------------------------------------------
 10- 0   I 18.558  I 102.00  I        I          I         I           I        I  9-35      42.9
                             I 13.348 I   30.00  I 106.26  I   7647.35 I 159.31 I
 10-30   I  8.139  I 116.00  I        I          I         I           I        I
                             I  6.193 I   15.00  I 109.03  I   3640.74 I  37.92 I
 10-45   I  4.248  I  95.70  I        I          I         I           I        I
                             I  2.157 I   30.00  I  95.59  I   1111.67 I  23.15 I
 11-15   I  0.066  I  89.10  I        I          I         I           I        I
                             I  0.044 I   15.00  I  84.83  I     20.35 I   0.21 I
 11-30   I  0.023  I  72.60  I        I          I         I           I        I
--------------------------------------------------------------------------------------------------------
                                                              TOTAL=     220.61 I  DIVERTED= 403.00
```

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 8-1-75 LAWRENCE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
6-50	16.187	240.00							
7- 5	78.785	533.00	47.486	15.00	483.06	123664.00	1288.16	4-50	25.0
7-20	84.720	227.00	81.752	15.00	374.44	165031.21	1719.07		
7-35	73.472	263.00	79.095	15.00	243.72	103925.32	1082.55		
7-50	67.356	238.00	70.414	15.00	251.04	95297.70	992.68		
8- 5	67.537	202.00	67.446	15.00	219.97	79985.26	833.17		
8-20	41.613	165.00	54.574	15.00	187.89	55281.77	575.85		
8-35	30.554	193.00	36.083	15.00	176.85	34403.34	358.36		
8-50	22.074	180.00	26.313	15.00	187.54	26605.62	277.14		
9-50	10.392	105.00	16.233	60.00	155.99	13651.50	568.81		
						TOTAL=	7695.83		

OVERFLOW POINT D SAMPLE SUSPENDED SOLIDS 8-1-75

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
6-50	17.690	158.00							
7- 5	92.821	810.00	55.255	15.00	705.63	210198.18	2189.56	4-45	3.0
7-20	79.125	436.00	85.973	15.00	637.89	295656.18	3079.75	10-35	31.0
7-35	57.705	621.00	68.415	15.00	514.01	189586.15	1974.85		
7-50	54.239	240.00	55.972	15.00	436.39	131682.90	1371.69		
8- 5	46.312	154.00	50.275	15.00	200.38	54313.52	565.76		
8-20	30.440	194.00	38.375	15.00	169.86	35142.83	366.07		
8-35	20.597	118.00	25.518	15.00	163.32	22469.48	234.05		
8-50	11.857	54.00	16.227	15.00	94.61	8277.25	86.22		
9-50	2.133	66.00	6.994	60.00	55.92	2105.36	87.72		
						TOTAL=	9955.70	DIVERTED=-2259.87	

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 8-1-75 LAWRENCE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
6-50	16.187	137.00							
			47.486	15.00	168.52	43142.07	449.39	4-50	54.0
7- 5	78.785	175.00							
			81.752	15.00	116.81	51482.94	536.28		
7-20	84.720	62.70							
			79.095	15.00	78.02	33271.60	346.57		
7-35	73.472	95.70							
			70.414	15.00	80.72	30645.56	319.22		
7-50	67.356	64.40							
			67.446	15.00	66.85	24308.46	253.21		
8- 5	67.537	69.30							
			54.574	15.00	63.00	18538.50	193.10		
8-20	41.613	52.80							
			36.083	15.00	56.99	11086.48	115.48		
8-35	30.554	62.70							
			26.313	15.00	63.41	8995.82	93.70		
8-50	22.074	64.40							
			16.233	60.00	62.79	5495.79	228.99		
9-50	10.392	59.40							
						TOTAL=	2535.98		

OVERFLCW POINT D SAMPLE BOD 8-1-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
6-50	17.690	59.40							
			55.255	15.00	114.49	34107.76	355.28	4-45	33.0
7- 5	92.821	125.00							
			85.973	15.00	137.42	63694.56	663.48	10-35	39.6
7-20	79.125	152.00							
			68.415	15.00	140.61	51862.50	540.23		
7-35	57.705	125.00							
			55.972	15.00	99.61	30057.61	313.10		
7-50	54.239	72.60							
			50.275	15.00	62.74	17005.95	177.14		
8- 5	46.312	51.20							
			38.375	15.00	58.37	12077.80	125.81		
8-20	30.440	69.30							
			25.518	15.00	65.30	8984.10	93.58		
8-35	20.597	59.40							
			16.227	15.00	49.17	4301.46	44.80		
8-50	11.857	31.40							
			6.994	60.00	33.15	1250.23	52.09		
9-50	2.133	42.90							
						TOTAL=	2365.54	DIVERTED= 170.43	

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 8-1-75 MONTROSE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
7- 0	54.332	374.00	56.635	15.00	405.21	123723.23	1288.78	5-00	46.0
7-15	58.938	434.00	54.633	15.00	490.65	144512.65	1505.34		
7-30	50.328	557.00	45.777	15.00	475.04	117236.57	1221.21		
7-45	41.227	375.00	35.910	15.00	303.01	58661.06	611.05		
8- 0	30.593	206.00	28.678	15.00	195.26	30189.95	314.47		
8-15	26.764	183.00	23.556	15.00	154.92	19674.72	204.94		
8-30	20.349	118.00							
						TOTAL=	5145.81		

OVERFLOW POINT D SAMPLE SUSPENDED SOLIDS 8-1-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
7- 0	15.456	665.00	20.020	15.00	574.12	61968.27	645.50	5-00	18.0
7-15	24.586	517.00	23.347	15.00	507.05	63823.67	664.82	8-40	95.0
7-30	22.110	496.00	18.376	15.00	447.78	44363.32	462.11		
7-45	14.644	375.00	13.666	15.00	310.00	22840.41	237.92		
8- 0	12.689	235.00	8.014	30.00	209.16	9037.20	188.27		
8-30	3.340	111.00							
						TOTAL=	2198.64	DIVERTED=2947.16	

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BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 8-1-75 MONTROSE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
7- 0	54.332	116.00						5-00	56.1
7-15	58.938	102.00	56.635	15.00	108.71	33193.37	345.76		
7-30	50.328	163.00	54.633	15.00	130.09	38317.46	399.14		
7-45	41.227	95.70	45.777	15.00	132.69	32747.78	341.12		
8- 0	30.593	52.80	35.910	15.00	77.42	14989.17	156.13		
8-15	26.764	34.70	28.678	15.00	44.35	6857.50	71.43		
8-30	20.349	46.20	23.556	15.00	39.66	5037.51	52.47		

TOTAL= 1366.07 I

OVERFLOW POINT D SAMPLE BOD 8-1-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
7- 0	15.456	172.00						5-00	26.4
7-15	24.586	102.00	20.020	15.00	129.01	13925.69	145.05	8-40	46.2
7-30	22.110	106.00	23.347	15.00	103.89	13077.22	136.22		
7-45	14.644	69.30	18.376	15.00	91.37	9052.93	94.30		
8- 0	12.689	42.90	13.666	15.00	57.04	4202.84	43.77		
8-30	3.340	56.10	8.014	30.00	45.65	1972.41	41.09		

TOTAL= 460.45 I DIVERTED= 905.61

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BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

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BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

PAGE NUMBER

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 8-1-75 IRVING

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
7- 0	51.798	289.00	53.498	15.00	357.61	103139.87	1074.37	5-15	33.0
7-15	55.198	422.00	48.622	15.00	405.13	106196.59	1106.21		
7-30	42.046	383.00	36.422	15.00	351.71	69061.06	719.38		
7-45	30.799	309.00	27.081	15.00	293.03	42782.58	445.65		
8- 0	23.363	272.00	20.252	15.00	228.83	24984.61	260.25		
8-15	17.142	170.00							
						TOTAL=	3605.88		

OVERFLCW POINT D SAMPLE SUSPENDED SOLIDS 8-1-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
7- 0	30.830	374.00	31.401	15.00	433.56	73395.95	764.54	5-15	34.0
7-15	31.972	491.00	27.055	15.00	360.89	52638.82	548.32		
7-30	22.138	173.00	16.722	15.00	215.93	19466.30	202.77		
7-45	11.306	300.00	7.650	15.00	317.49	13094.83	136.40		
8- 0	3.995	367.00	2.186	15.00	348.67	4110.03	42.81		
8-15	0.378	155.00							
						TOTAL=	1694.85	DIVERTED=1911.02	

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 8-1-75 IRVING

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
7- 0	51.798	142.00	53.498	15.00	130.13	37532.35	390.96	5-15	56.1
7-15	55.198	119.00	48.622	15.00	115.97	30399.51	316.66		
7-30	42.046	112.00	36.422	15.00	108.61	21327.76	222.16		
7-45	30.799	104.00	27.081	15.00	84.76	12374.83	128.90		
8- 0	23.363	59.40	20.252	15.00	58.00	6332.97	65.96		
8-15	17.142	56.10							
						TOTAL=	1124.66		

OVERFLCW POINT D SAMPLE BOD 8-1-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
7- 0	30.830	112.00	31.401	15.00	121.16	20511.21	213.65	5-15	29.7
7-15	31.972	130.00	27.055	15.00	109.21	15929.79	165.93		
7-30	22.138	79.20	16.722	15.00	71.39	6435.85	67.04		
7-45	11.306	56.10	7.650	15.00	57.82	2384.88	24.84		
8- 0	3.995	62.70	2.186	15.00	62.69	739.08	7.69		
8-15	0.378	62.70							
						TOTAL=	479.17	DIVERTED=	645.48

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PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 8-11-75 LAWRENCE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
3-40	75.265	339.00	73.738	15.00	409.99	162985.65	1697.76	3-20	187.0
3-55	72.211	484.00	64.884	15.00	412.59	144321.90	1503.35		
4-10	57.557	323.00	54.601	15.00	335.29	98698.14	1028.10		
4-25	51.646	349.00	44.852	15.00	300.20	72590.92	756.15		
4-40	38.058	234.00	33.948	15.00	220.81	40412.92	420.96		
4-55	29.838	204.00	29.271	15.00	223.12	35209.85	366.76		
5-10	28.705	243.00	27.871	15.00	175.09	26308.80	274.04		
5-25	27.037	103.00	25.775	30.00	155.78	21646.77	450.97		
5-55	24.513	214.00							
						TOTAL=	6498.14		

OVERFLOW POINT D SAMPLE SUSPENDED SOLIDS 8-11-75

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
3-40	56.096	726.00	60.388	15.00	564.26	183702.12	1913.56	3-20	27.0
3-55	64.681	424.00	55.640	15.00	333.54	100051.21	1042.20	6-40	150.0
4-10	46.599	208.00	42.576	15.00	222.48	51068.46	531.96		
4-25	38.554	240.00	35.409	15.00	192.61	36769.46	383.01		
4-40	32.264	136.00	25.370	15.00	118.88	16260.21	169.37		
4-55	18.476	89.00	15.480	15.00	74.88	6249.89	65.10		
5-10	12.486	54.00	13.771	15.00	46.89	3481.50	36.26		
5-25	15.057	41.00	13.529	30.00	51.64	3766.92	78.47		
5-55	12.002	65.00							
						TOTAL=	4219.96	DIVERTED=2278.17	

EPA-287 (Cin.)
(4-76)

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TOTAL POINT B SAMPLE BOD 8-11-75 LAWRENCE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
3-40	75.265	101.00							
3-55	72.211	90.00	73.738	15.00	95.61	38009.13	395.92	3-20	89.0
4-10	57.557	71.00	64.884	15.00	81.57	28533.72	297.22		
4-25	51.646	85.00	54.601	15.00	77.62	22848.61	238.00		
4-40	38.058	69.00	44.852	15.00	78.21	18911.66	196.99		
4-55	29.838	74.00	33.946	15.00	71.19	13030.27	135.73		
5-10	28.705	77.00	29.271	15.00	75.47	11909.68	124.05		
5-25	27.037	55.00	27.871	15.00	66.32	9966.26	103.81		
5-55	24.513	60.00	25.775	30.00	57.37	7972.90	166.10		
						TOTAL=	1657.86		

OVERFLOW POINT D SAMPLE BOD 8-11-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
3-40	56.096	105.00							
3-55	64.681	107.00	60.388	15.00	106.07	34532.40	359.71	3-20	36.0
4-10	46.599	77.00	55.640	15.00	94.43	28327.39	295.07	6-40	39.0
4-25	38.554	92.00	42.576	15.00	83.79	19232.91	200.34		
4-40	32.264	58.00	35.409	15.00	76.50	14605.18	152.13		
4-55	18.476	39.00	25.370	15.00	51.08	6986.50	72.77		
5-10	12.486	34.00	15.480	15.00	36.98	3086.62	32.15		
5-25	15.057	29.00	13.771	15.00	31.26	2321.33	24.18		
5-55	12.002	36.00	13.529	30.00	32.10	2341.68	48.78		
						TOTAL=	1185.16	DIVERTED= 472.70	

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 8-11-70 MONTROSE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
4-15	26.943	532.00	22.776	15.00	433.13	53183.75	553.99	3-35	563.0
4-30	18.609	290.00							
						TOTAL=	553.99		

OVERFLCW POINT D SAMPLE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
4-15	11.072	730.00	12.749	15.00	499.73	34346.98	357.78	4-00	137.0
4-30	14.426	323.00						6-15	74.0
						TOTAL=	357.78	DIVERTED=	196.21

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 8-11-75 MONTROSE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
4-15	26.943	108.00	22.776	15.00	94.92	11655.85	121.41	3-35	105.0
4-30	18.609	76.00							
						TOTAL=	121.41		

OVERFLOW POINT D SAMPLE

								RIVER SAMPLE TIME	RIVER SAMPLE MG/L
4-15	11.072	25.00	12.749	15.00	72.52	4984.68	51.92	4-00	52.0
4-30	14.426	109.00						6-15	37.0
						TOTAL=	51.92	DIVERTED=	69.49

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EPA-287 (Cin.)
(4-70)

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 8-11-75 IRVING

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
3-40	53.851	408.00							
4- 0	36.312	291.00	45.081	20.00	360.87	87707.45	1218.15		
4-15	30.799	300.00	33.555	15.00	295.13	53389.15	556.13		
4-30	21.159	220.00	25.979	15.00	267.42	37453.64	390.14		
4-45	16.512	207.00	18.835	15.00	214.30	21760.98	226.67		
						TOTAL=	2391.11		

OVERFLOW POINT D SAMPLE SUSPENDED SOLIDS 8-11-75

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
3-40	33.424	326.00							
4- 0	15.301	434.00	24.362	20.00	359.91	47271.28	656.54	3-30	23.0
4-15	10.815	466.00	13.058	15.00	447.25	31485.03	327.96		
4-30	4.321	192.00	7.567	15.00	387.77	15821.25	164.80	5-25	158.0
4-45	0.866	271.00	2.593	15.00	205.18	2868.90	29.88		
						TOTAL=	1179.20	DIVERTED=1211.91	

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 8-11-75 IRVING

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
3-40	53.851	106.00	45.081	20.00	105.59	25664.12	356.44		
4- 0	36.312	105.00	33.555	15.00	90.31	16337.89	170.18		
4-15	30.799	73.00	25.979	15.00	71.37	9995.85	104.12		
4-30	21.159	69.00	18.835	15.00	73.38	7451.59	77.62		
4-45	16.512	79.00							
						TOTAL=	708.37		

OVERFLOW POINT D SAMPLE BOD 8-11-75

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
3-40	33.424	84.00	24.362	20.00	66.10	8681.63	120.57	3-30	36.0
4- 0	15.301	27.00	13.058	15.00	47.29	3329.17	34.67		
4-15	10.815	76.00	7.567	15.00	62.01	2530.05	26.35	5-25	65.0
4-30	4.321	27.00	2.593	15.00	34.67	484.88	5.05		
4-45	0.866	73.00							
						TOTAL=	186.66	DIVERTED=	521.71

EPA-287 (Cin.)
(4-76)

TOTAL POINT D SAMPLE SUSPENDED SOLIDS 10-24-75 LAWRENCE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	MG/L
4-10	33.110	620.00							
4-25	76.542	678.00	54.825	15.00	660.48	195220.81	2033.55	1-40	89.0
4-40	75.965	588.00	76.253	15.00	633.17	260289.00	2711.34	3-45	107.0
4-55	59.322	496.00	67.643	15.00	547.65	199715.53	2060.37		
5-10	57.406	441.00	58.364	15.00	468.95	147553.15	1537.01		
5-25	45.832	403.00	51.619	15.00	424.13	118027.78	1229.45		
5-40	39.260	293.00	42.545	15.00	352.24	80794.65	841.61		
5-55	28.014	259.00	33.637	15.00	276.84	50565.07	526.71		
6-10	21.563	220.00	24.788	15.00	242.03	32345.08	336.92		
7-10	13.010	88.00	17.286	60.00	170.32	15873.32	661.38		
						TOTAL=	11958.37		

OVERFLOW POINT D SAMPLE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	MG/L
4-10	41.945	763.00							
4-25	70.471	400.00	56.208	15.00	535.44	162251.00	1690.11	1-40	33.0
4-40	64.439	1120.00	67.455	15.00	743.90	270524.50	2817.96	3-45	132.0
4-55	47.111	634.00	55.775	15.00	914.74	275052.93	2865.13		
5-10	32.563	462.00	39.836	15.00	563.70	121063.31	1261.07		
5-25	29.286	292.00	30.924	15.00	381.50	63602.89	662.53		
5-40	23.591	288.00	26.438	15.00	290.21	41364.98	430.88		
5-55	15.552	475.00	19.571	15.00	362.29	38226.53	398.19		
6-10	6.510	220.00	11.031	15.00	399.75	23773.02	247.63		
7-10	1.387	106.00	3.948	60.00	199.97	4256.85	177.36		
						TOTAL=	10550.89	DIVERTED=1407.47	

EPA-287 (Cin.)
(4-76)

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TOTAL POINT B SAMPLE SUSPENDED SOLIDS 10-24-75 LAWRENCE

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
8-10	95.975	143.00	82.751	60.00	110.23	49176.71	2049.02		
9-10	69.528	65.00	56.370	60.00	61.93	18821.49	784.22		
10-10	43.213	57.00	29.364	60.00	56.73	8981.63	374.23		
11-10	15.516	56.00	16.401	60.00	42.82	3786.58	157.77		
12-10	17.286	31.00							
						TOTAL=	3365.26		

OVERFLOW POINT D SAMPLE

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
8-10	36.688	150.00	31.363	60.00	122.60	20729.97	863.74	7-27	99.0
9-10	26.039	84.00	21.857	60.00	95.72	11279.92	469.99	12-30	62.0
10-10	17.676	113.00	10.816	60.00	108.97	6354.90	264.78		
11-10	3.958	91.00	3.227	60.00	108.02	1879.52	78.31		
12-10	2.497	135.00							
						TOTAL=	1676.84	DIVERTED=1688.42	

EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 10-24-75 LAWRENCE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY(	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
4-10	33.110	79.90	54.825	15.00	142.79	42205.74	439.64	1-40	55.7
4-25	76.542	170.00	76.253	15.00	97.42	40050.56	417.19	3-45	52.1
4-40	75.965	24.30	67.643	15.00	61.00	22245.54	231.72		
4-55	59.322	108.00	58.364	15.00	170.45	53633.64	558.68		
5-10	57.406	235.00	51.619	15.00	174.13	48458.67	504.77		
5-25	45.832	97.90	42.545	15.00	70.40	16147.91	168.20		
5-40	39.260	38.30	33.637	15.00	46.96	8515.97	88.70		
5-55	28.014	59.10	24.788	15.00	50.05	6688.95	69.67		
6-10	21.563	38.30	17.286	60.00	60.53	5641.86	235.07		
7-10	13.010	97.40							
						TOTAL=	2713.69		

OVERFLOW POINT D SAMPLE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY(	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
4-10	41.945	330.00	56.208	15.00	219.04	66374.71	691.40	1-40	24.3
4-25	70.471	153.00	67.455	15.00	221.30	80478.00	838.31	3-45	24.3
4-40	64.439	296.00	55.775	15.00	228.42	68685.14	715.47		
4-55	47.111	136.00	39.836	15.00	134.36	28856.85	300.59		
5-10	32.563	132.00	30.924	15.00	102.64	17112.18	178.25		
5-25	29.286	70.00	26.438	15.00	219.01	31216.45	325.17		
5-40	23.591	404.00	19.571	15.00	286.39	30218.01	314.77		
5-55	15.552	108.00	11.031	15.00	110.95	6598.12	68.73		
6-10	6.510	118.00	3.948	60.00	102.77	2187.68	91.15		
7-10	1.387	31.30							
						TOTAL=	3523.85	DIVERTED=-810.16	

TOTAL POINT B SAMPLE BOD 10-24-75 LAWRENCE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
8-10	95.975	41.70							
9-10	69.528	97.40	82.751	60.00	65.09	29042.22	1210.09		
10-10	43.213	184.00	56.370	60.00	130.59	39687.00	1653.62		
11-10	15.516	93.90	29.364	60.00	160.19	25360.01	1056.66		
12-10	17.286	59.10	16.401	60.00	75.56	6681.03	278.37		
						TOTAL=	4198.76		

OVERFLOW POINT D SAMPLE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
8-10	36.688	129.00							
9-10	26.039	55.70	31.363	60.00	98.57	16666.85	694.45	7-27	104.0
10-10	17.676	41.70	21.857	60.00	50.03	5896.38	245.68	12-30	7.0
11-10	3.958	45.20	10.816	60.00	42.34	2469.08	102.87		
12-10	2.497	73.00	3.227	60.00	55.95	973.58	40.56		
						TOTAL=	1083.57	DIVERTED=3115.19	

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EPA-287 (Cin.)
(4-76)

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TOTAL POINT B SAMPLE  SUSPENDED SOLIDS  10-24-75  MONTROSE

------------------------------------------------------------------------------------------------------------
 TIME OF  | C(CFS)  | SAMPLE  |  QAVE  | TIME INT | SAMPLE  |   SAMPLE   | SAMPLE  |   GRAB SAMPLE
   MST    |         | (MG/L)  | (CFS)  |  (MIN)   | WT AVE  |  LBS/DAY   |  LBS    |  TIME     MG/L
------------------------------------------------------------------------------------------------------------
  4-45    | 46.488  | 699.00  |        |          |         |            |         |  2-00     44.0
          |         |         | 41.870 |   15.00  | 663.85  | 149850.34  | 1560.94 |
  5- 0    | 37.253  | 620.00  |        |          |         |            |         |  4-00     74.0
          |         |         | 33.016 |   15.00  | 554.18  |  98642.35  | 1027.52 |
  5-15    | 28.780  | 469.00  |        |          |         |            |         |
          |         |         | 26.612 |   15.00  | 379.44  |  54438.42  |  567.06 |
  5-30    | 24.445  | 274.00  |        |          |         |            |         |
          |         |         | 22.721 |   15.00  | 237.95  |  29147.77  |  303.62 |
  5-45    | 20.997  | 196.00  |        |          |         |            |         |
          |         |         |        |          |         |            |         |
------------------------------------------------------------------------------------------------------------
                                                             TOTAL=      3459.15  |
------------------------------------------------------------------------------------------------------------
CVERFLOW POINT D SAMPLE                                                           |   RIVER SAMPLE
                                                                                  |  TIME     MG/L
------------------------------------------------------------------------------------------------------------
  4-45    |  7.883  | 316.00  |        |          |         |            |         |  2-20     12.0
          |         |         | 10.605 |   15.00  | 503.24  |  28771.66  |  299.70 |
  5- 0    | 13.327  | 614.00  |        |          |         |            |         |  6-10     25.0
          |         |         | 14.068 |   15.00  | 660.31  |  50081.48  |  521.68 |
  5-15    | 14.810  | 702.00  |        |          |         |            |         |
          |         |         | 15.688 |   15.00  | 587.42  |  47684.43  |  517.54 |
  5-30    | 16.568  | 485.00  |        |          |         |            |         |
          |         |         | 10.271 |   15.00  | 423.85  |  23470.73  |  244.48 |
  5-45    |  3.975  | 169.00  |        |          |         |            |         |
          |         |         |        |          |         |            |         |
------------------------------------------------------------------------------------------------------------
                                                             TOTAL=      1593.41  |  DIVERTED=1875.73
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TCTAL POINT B SAMPLE SUSPENDED SOLIDS 10-24-75 MONTROSE

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
9- 0	45.939	63.00	43.184	15.00	65.80	15320.97	159.59	8-30	164.0
9-15	40.430	69.00	38.224	15.00	70.88	14607.27	152.15		
9-30	36.019	73.00							
						TOTAL=	311.75		

CVERFLCW POINT D SAMPLE

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
9- 0	38.331	86.00	23.916	15.00	85.60	11037.24	114.97	10-50	81.0
9-15	9.502	84.00	8.368	15.00	68.43	3097.59	32.16		
9-30	7.235	48.00							
						TOTAL=	147.13	DIVERTED=	164.51

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PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE BOD 10-24-75 MC.TRUSE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	CAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
4-45	46.488	188.00							
5- 0	37.253	233.00	41.870	15.00	209.01	46955.45	489.11	2-00	73.0
5-15	28.780	41.70	33.016	15.00	147.62	26632.11	277.41	4-00	80.0
5-30	24.445	111.00	26.612	15.00	73.52	10549.04	109.88		
5-45	20.997	97.40	22.721	15.00	104.71	12826.72	133.61		
						TOTAL=	1010.03		

OVERFLOW POINT D SAMPLE

TIME OF MST	C(CFS)	SAMPLE (MG/L)	CAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
4-45	7.883	90.40							
5- 0	13.327	233.00	10.605	15.00	180.00	10291.06	107.19	2-20	13.9
5-15	14.810	243.00	14.068	15.00	238.26	18070.95	188.23	6-10	122.0
5-30	16.568	143.00	15.688	15.00	190.19	16087.11	167.57		
5-45	3.975	59.10	10.271	15.00	126.76	7019.57	73.12		
						TOTAL=	536.13	DIVERTED= 473.90	

EPA-287 (Cin.) (4-70)

TOTAL POINT B SAMPLE BOD 10-24-75 MONTROSE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
9- 0	45.339	6.70							
9-15	40.430	20.90	43.184	15.00	13.34	3107.35	32.36	8-30	69.6
9-30	36.019	34.70	38.224	15.00	27.40	5646.73	58.82		
						TOTAL=	91.18		

OVERFLOW POINT D SAMPLE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
9- 0	38.331	10.30							
9-15	9.502	7.00	23.916	15.00	9.64	1243.51	12.95	10-50	24.3
9-30	7.235	20.90	8.368	15.00	13.00	586.88	6.11		
						TOTAL=	19.06	DIVERTED=	72.12

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EPA-287 (Cin.)
(4-76)

TOTAL POINT B SAMPLE SUSPENDED SOLIDS 10-24-75 IRVING

TIME OF PST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	MG/L
4-30	37.041	417.00							
4-45	35.727	495.00	36.384	15.00	455.29	89305.78	930.26	2-35	24.0
5- 0	33.390	325.00	34.558	15.00	412.87	76921.54	801.26		
5-15	24.903	248.00	29.146	15.00	292.10	45898.81	478.11		
5-30	18.865	318.00	21.884	15.00	278.17	32818.21	341.85		
5-45	20.752	187.00	19.808	15.00	249.38	26631.09	277.40		
6- 0	16.723	179.00	18.737	15.00	183.43	18529.24	193.01		
						TOTAL=	3021.92		

OVERFLOW POINT D SAMPLE VALUES OBTAINED FROM POINT B SAMPLES

								RIVER SAMPLE TIME	MG/L
4-30	10.007	417.00							
4-45	15.970	495.00	12.988	15.00	464.95	32556.90	339.13		
5- 0	15.546	325.00	15.758	15.00	411.14	34927.71	363.83		
5-15	7.244	248.00	11.395	15.00	300.52	18461.64	192.30		
5-30	3.121	318.00	5.182	15.00	269.07	7517.82	78.31		
5-45	0.890	187.00	2.005	15.00	288.93	3123.88	32.54		
6- 0	0.116	179.00	0.503	15.00	186.07	504.58	5.25		
						TOTAL=	1011.38	DIVERTED=2010.54	

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TOTAL POINT B SAMPLE SUSPENDED SOLIDS 10-24-75 IRVING

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	GRAB SAMPLE TIME	GRAB SAMPLE MG/L
8-15	15.936	135.00							
8-30	63.346	183.00	39.640	15.00	173.35	37046.60	385.90		
9- 0	38.255	84.00	50.800	30.00	145.72	39909.43	831.44		
10- 0	25.491	8.00	31.873	60.00	53.60	9211.59	383.81		
						TOTAL=	1601.16		

OVERFLOW POINT D SAMPLE

TIME OF MST	Q(CFS)	SAMPLE (MG/L)	QAVE (CFS)	TIME INT (MIN)	SAMPLE WT AVE	SAMPLE LBS/DAY	SAMPLE LBS	RIVER SAMPLE TIME	RIVER SAMPLE MG/L
8-15	30.062	304.00						11-20	59.0
8-30	38.643	158.00	34.352	15.00	221.88	41091.97	428.04		
9- 0	33.910	73.00	36.276	30.00	118.27	23130.48	481.88		
10- 0	6.625	9.00	20.267	60.00	62.53	6833.33	284.72		
						TOTAL=	1194.64	DIVERTED= 406.51	

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TOTAL POINT B SAMPLE  BOD  10-24-75  IRVING

------------------------------------------------------------------------------------------------------------
TIME OF  I Q(CFS)  I SAMPLE  I   QAVE I TIME INT I SAMPLE  I    SAMPLE  I SAMPLE  I   GRAB SAMPLE
 MST     I         I (MG/L)  I  (CFS) I  (MIN)   I WT AVE  I   LBS/DAY  I  LBS    I  TIME       MG/L
------------------------------------------------------------------------------------------------------------
  4-30   I 37.041  I 539.00  I        I          I         I            I         I  2-35       48.7
         I         I         I 36.384 I   15.00  I 383.85  I   75292.37 I 784.29  I
  4-45   I 35.727  I 223.00  I        I          I         I            I         I
         I         I         I 34.558 I   15.00  I 157.25  I   29297.03 I 305.17  I
  5- 0   I 33.390  I  86.90  I        I          I         I            I         I
         I         I         I 29.146 I   15.00  I 115.13  I   18091.78 I 188.45  I
  5-15   I 24.903  I 153.00  I        I          I         I            I         I
         I         I         I 21.884 I   15.00  I 140.93  I   16626.84 I 173.19  I
  5-30   I 18.865  I 125.00  I        I          I         I            I         I
         I         I         I 19.808 I   15.00  I 154.33  I   16481.16 I 171.67  I
  5-45   I 20.752  I 181.00  I        I          I         I            I         I
         I         I         I 18.737 I   15.00  I 160.91  I   16255.28 I 169.32  I
  6- 0   I 16.723  I 136.00  I        I          I         I            I         I
         I         I         I        I          I         I            I         I
------------------------------------------------------------------------------------------------------------
                                                                TOTAL=    1792.12  I
------------------------------------------------------------------------------------------------------------
OVERFLCW POINT D SAMPLE VALUES OBTAINED FROM POINT B SAMPLES                      I   RIVER SAMPLE
                                                                                  I  TIME       MG/L
------------------------------------------------------------------------------------------------------------
  4-30   I 10.007  I 539.00  I        I          I         I            I         I
         I         I         I 12.988 I   15.00  I 344.73  I   24138.77 I 251.44  I
  4-45   I 15.970  I 223.00  I        I          I         I            I         I
         I         I         I 15.758 I   15.00  I 155.86  I   13241.17 I 137.92  I
  5- 0   I 15.546  I  86.90  I        I          I         I            I         I
         I         I         I 11.395 I   15.00  I 107.91  I    6629.08 I  69.05  I
  5-15   I  7.244  I 153.00  I        I          I         I            I         I
         I         I         I  5.182 I   15.00  I 144.56  I    4039.14 I  42.07  I
  5-30   I  3.121  I 125.00  I        I          I         I            I         I
         I         I         I  2.005 I   15.00  I 137.42  I    1485.82 I  15.47  I
  5-45   I  0.890  I 181.00  I        I          I         I            I         I
         I         I         I  0.503 I   15.00  I 175.81  I     476.74 I   4.96  I
  6- 0   I  0.116  I 136.00  I        I          I         I            I         I
         I         I         I        I          I         I            I         I
------------------------------------------------------------------------------------------------------------
                                                                TOTAL=     520.94  I  DIVERTED=1271.18
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TOTAL POINT B SAMPLE  BOD  10-24-75  IRVING

----------------------------------------------------------------------------------------------------------
TIME OF  I Q(CFS)  I SAMPLE  I   QAVE  I TIME INT I SAMPLE  I   SAMPLE  I SAMPLE I   GRAB SAMPLE
MST      I         I (MG/L)  I  (CFS)  I  (MIN)   I WT AVE  I  LBS/DAY  I  LBS   I  TIME      MG/L
----------------------------------------------------------------------------------------------------------
  8-15   I 15.936  I  45.20  I         I          I         I           I        I
  8-30   I 63.346  I  73.00  I 39.640  I  15.00   I  67.41  I  14406.48 I 150.06 I
  9- 0   I 38.255  I  27.80  I 50.800  I  30.00   I  55.98  I  15331.53 I 319.40 I
 10- 0   I 25.491  I   3.50  I 31.873  I  60.00   I  18.08  I   3107.16 I 129.46 I
         I         I         I         I          I         I           I        I
----------------------------------------------------------------------------------------------------------
                                                               TOTAL=     598.93 I
----------------------------------------------------------------------------------------------------------
OVERFLOW POINT D SAMPLE
                                                                                 I  RIVER SAMPLE
                                                                                 I  TIME      MG/L
----------------------------------------------------------------------------------------------------------
  8-15   I 30.062  I 115.00  I         I          I         I           I        I  11-20      7.0
  8-30   I 38.643  I  41.70  I 34.352  I  15.00   I  73.77  I  13662.45 I 142.31 I
  9- 0   I 33.910  I  24.30  I 36.276  I  30.00   I  33.56  I   6564.78 I 136.76 I
 10- 0   I  6.625  I   7.00  I 20.267  I  60.00   I  21.47  I   2346.16 I  97.75 I
         I         I         I         I          I         I           I        I
----------------------------------------------------------------------------------------------------------
                                                               TOTAL=     376.84 I  DIVERTED= 222.09
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APPENDIX B

PLOTS OF COMPUTED AND MEASURED OVERFLOW QUANTITY AND QUALITY

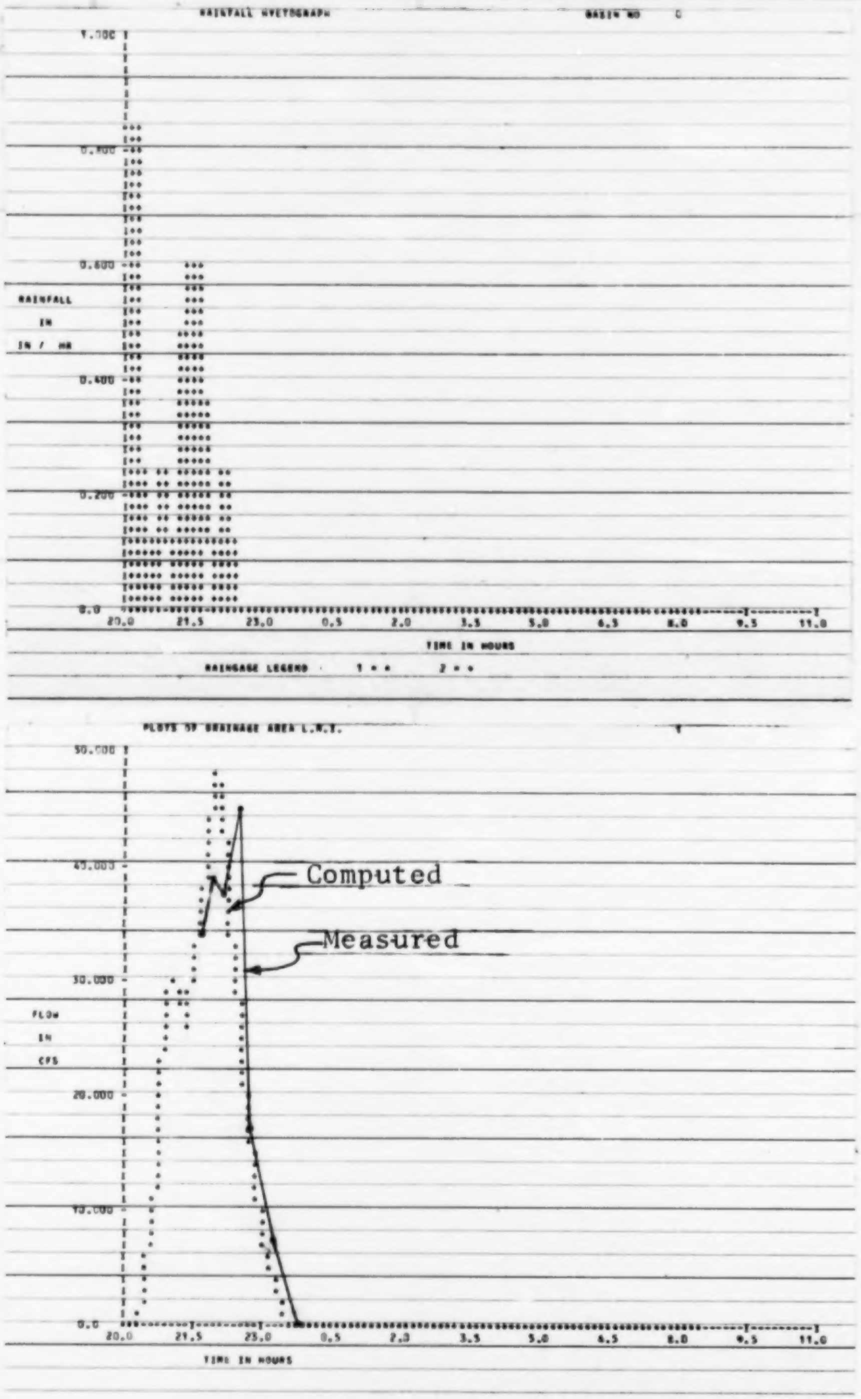

Figure B-1 Lawrence Avenue Overflow Results - Storm of July 23, 1975

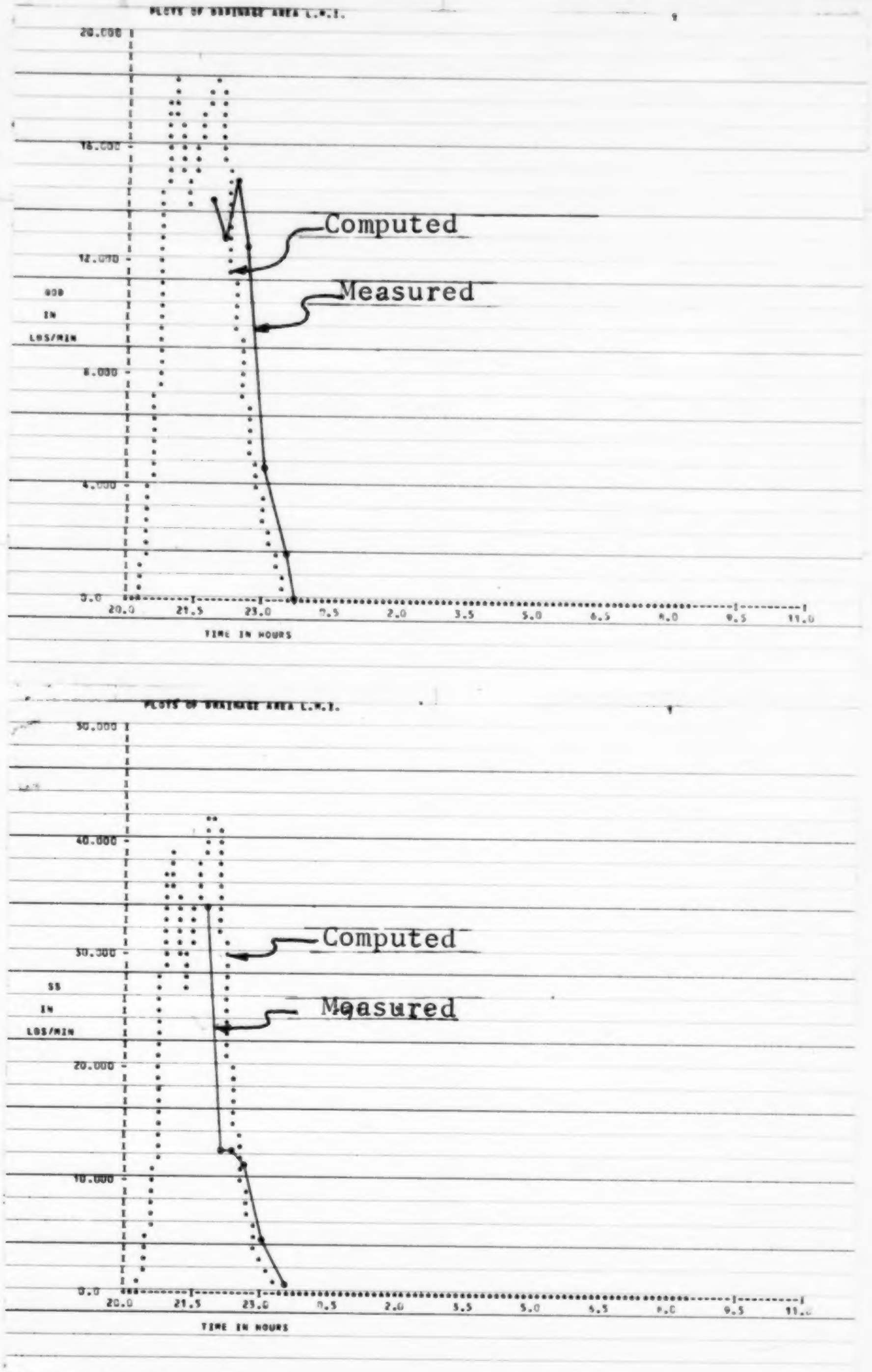

Figure B-2 Lawrence Avenue Overflow Results - Storm of July 23, 1975

EPA-287 (Cin.) (4-76)

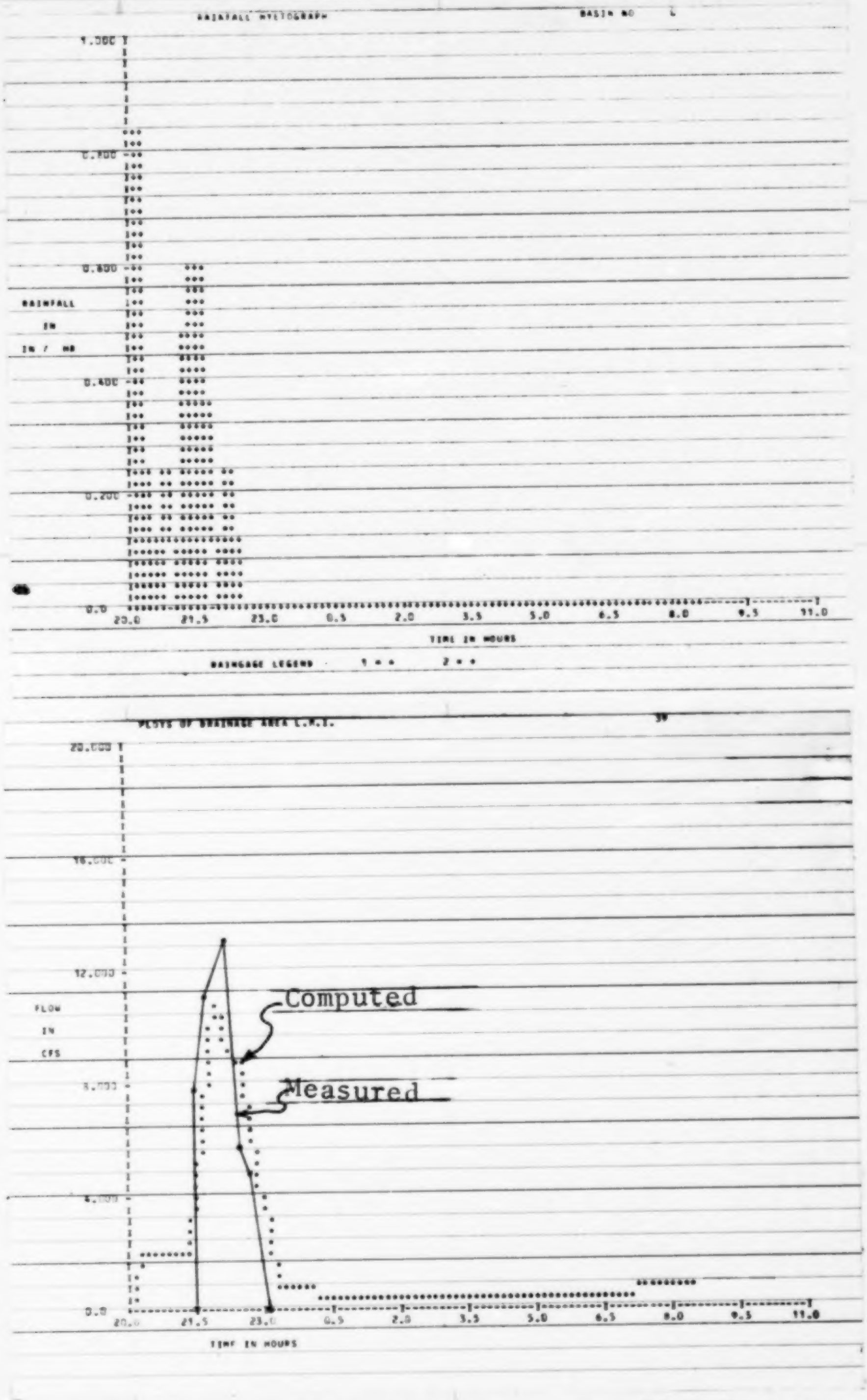

Figure B-3 Montrose Avenue Overflow Results - Storm of July 23, 1975

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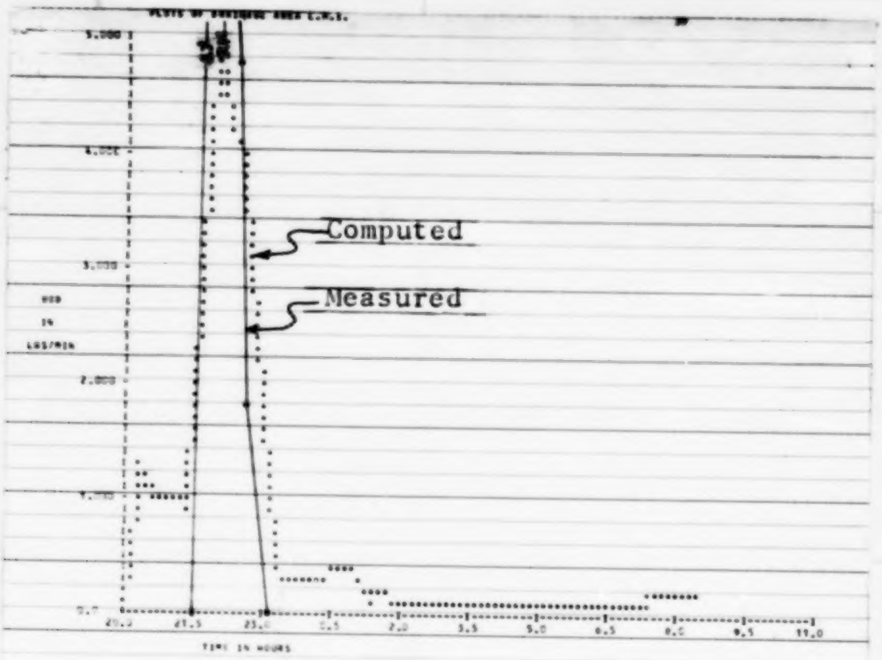

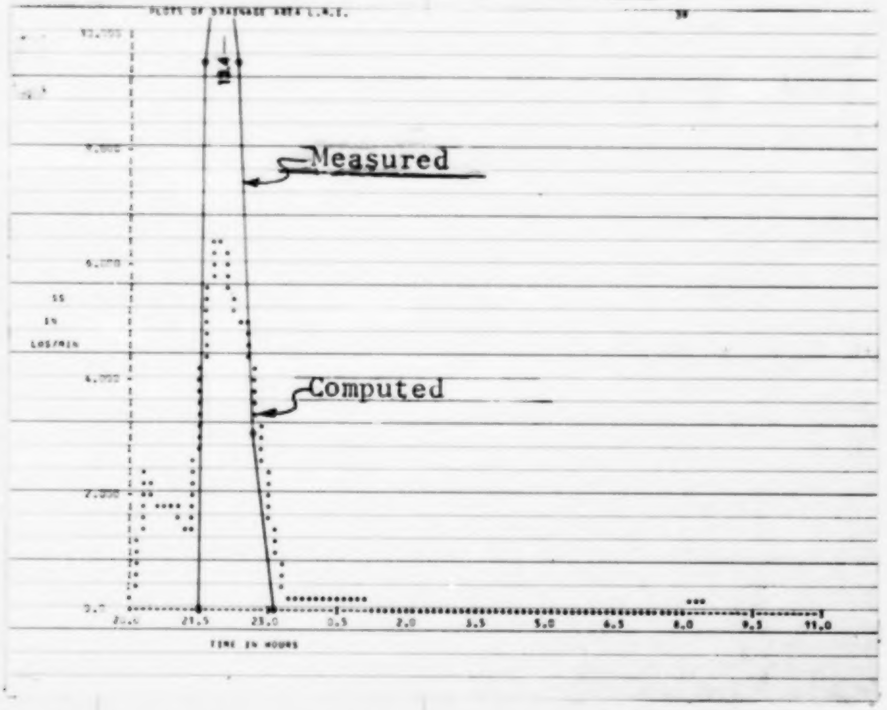

Figure B-4 Montrose Avenue Overflow Results - Storm of July 23, 1975

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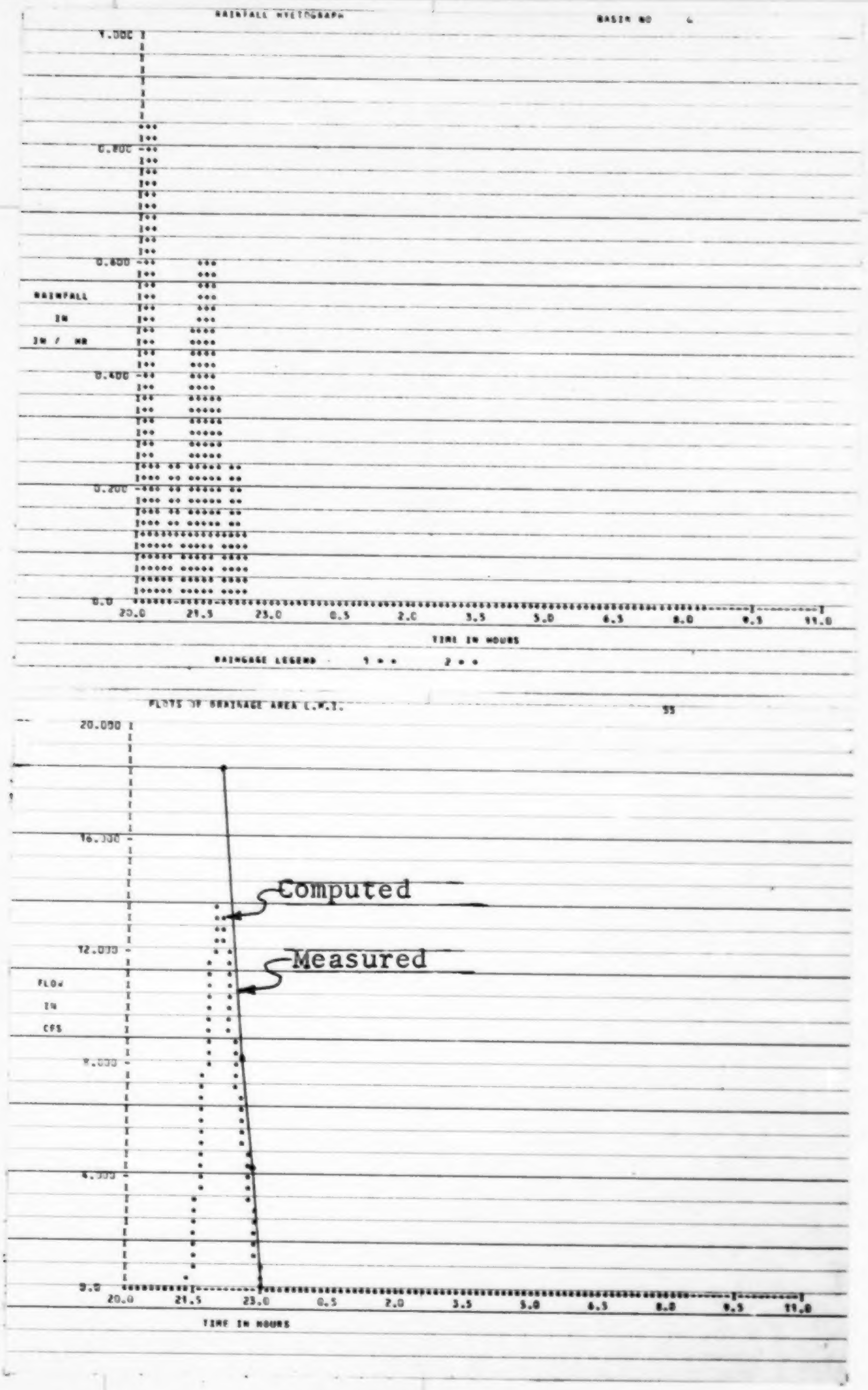

Figure B-5 Irving Park Road Overflow Results - Storm of July 23, 1975

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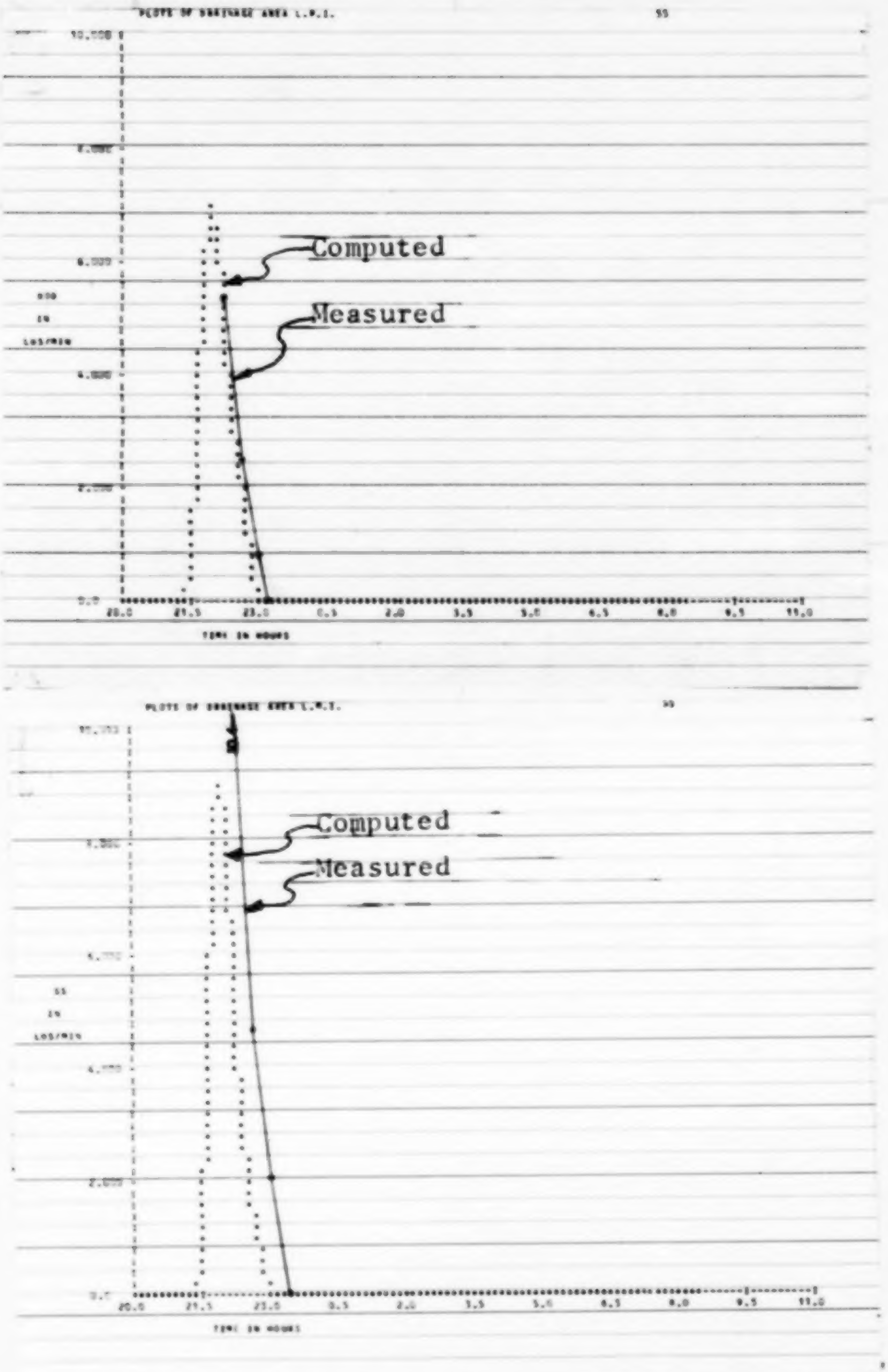

Figure B-6 Irving Park Road Overflow Results - Storm of July 23, 1975

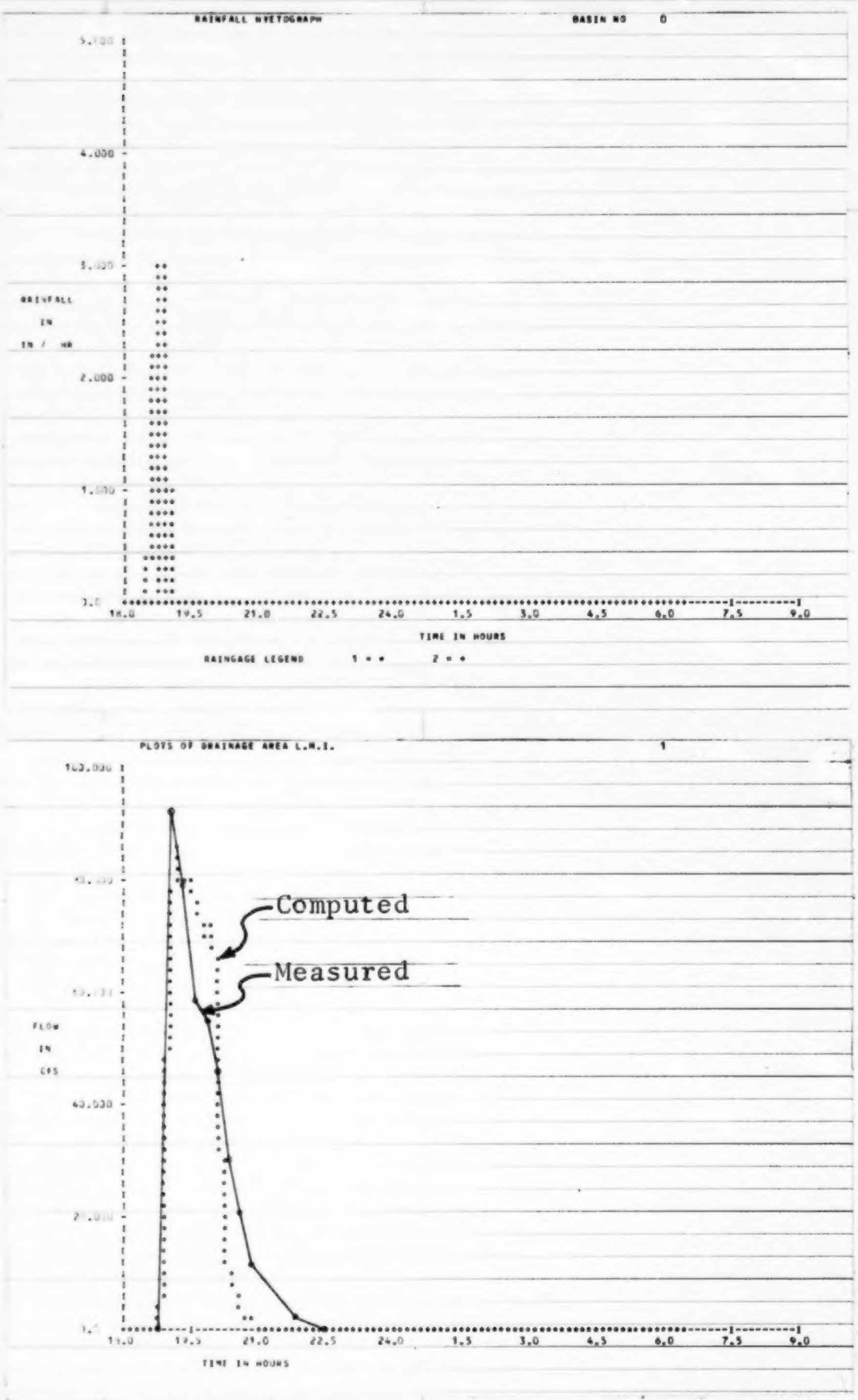

Figure B-7 Lawrence Avenue Overflow Results - Storm of August 1, 1975

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PAGE NUMBER
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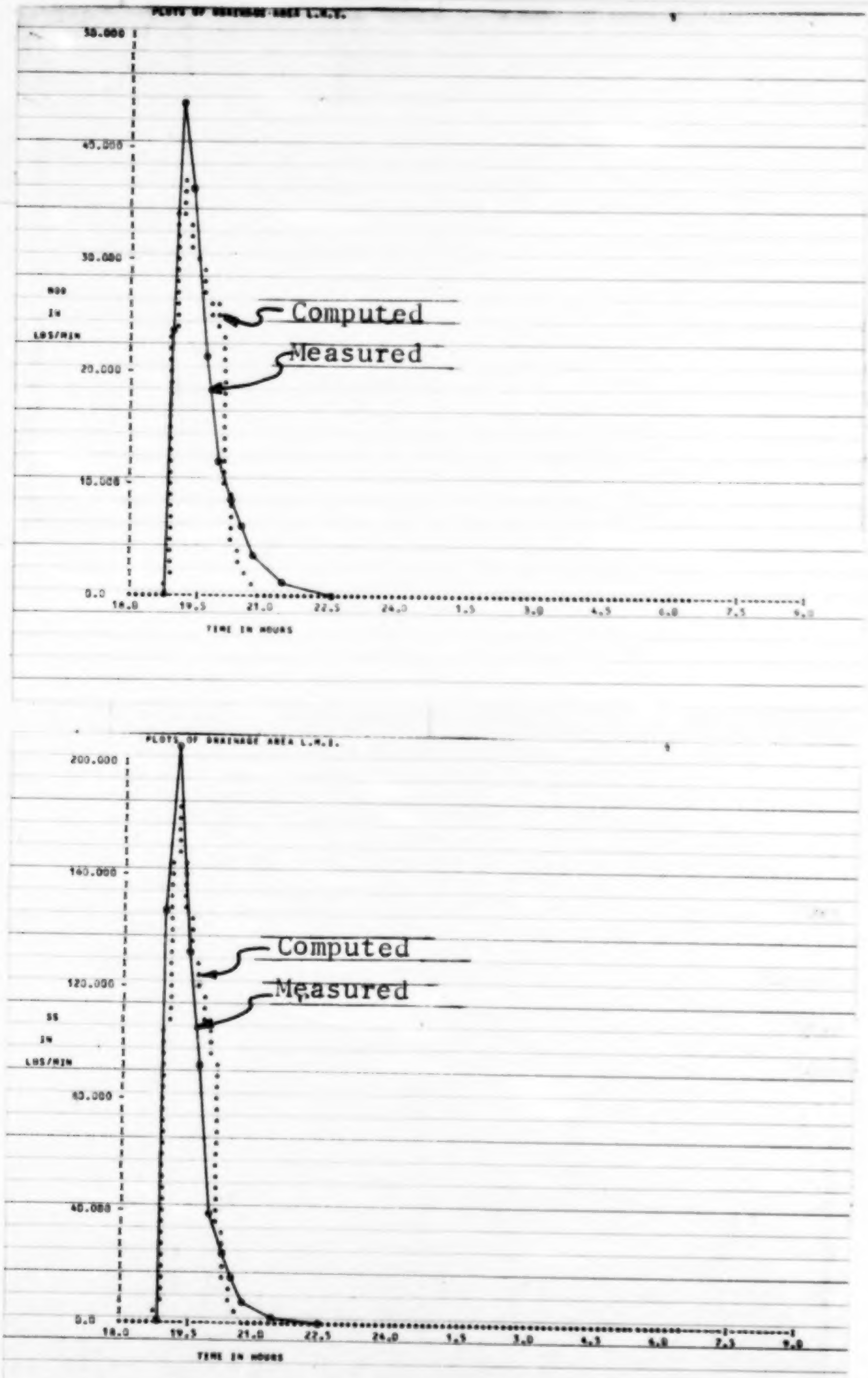

Figure B-8 Lawrence Avenue Overflow Results - Storm of August 1, 1975

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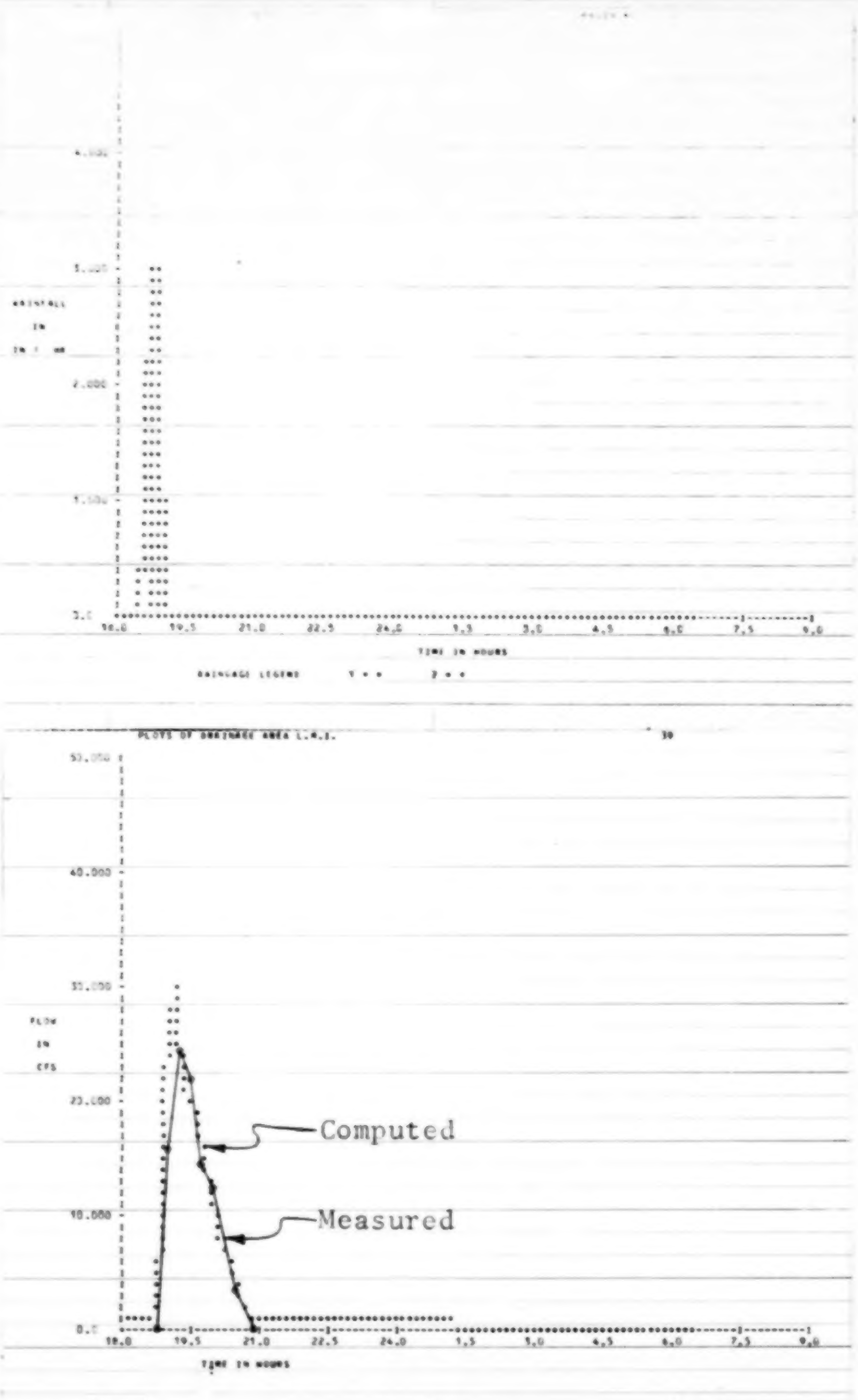

Figure B-9 Montrose Avenue Overflow Results - Storm of August 1, 1975

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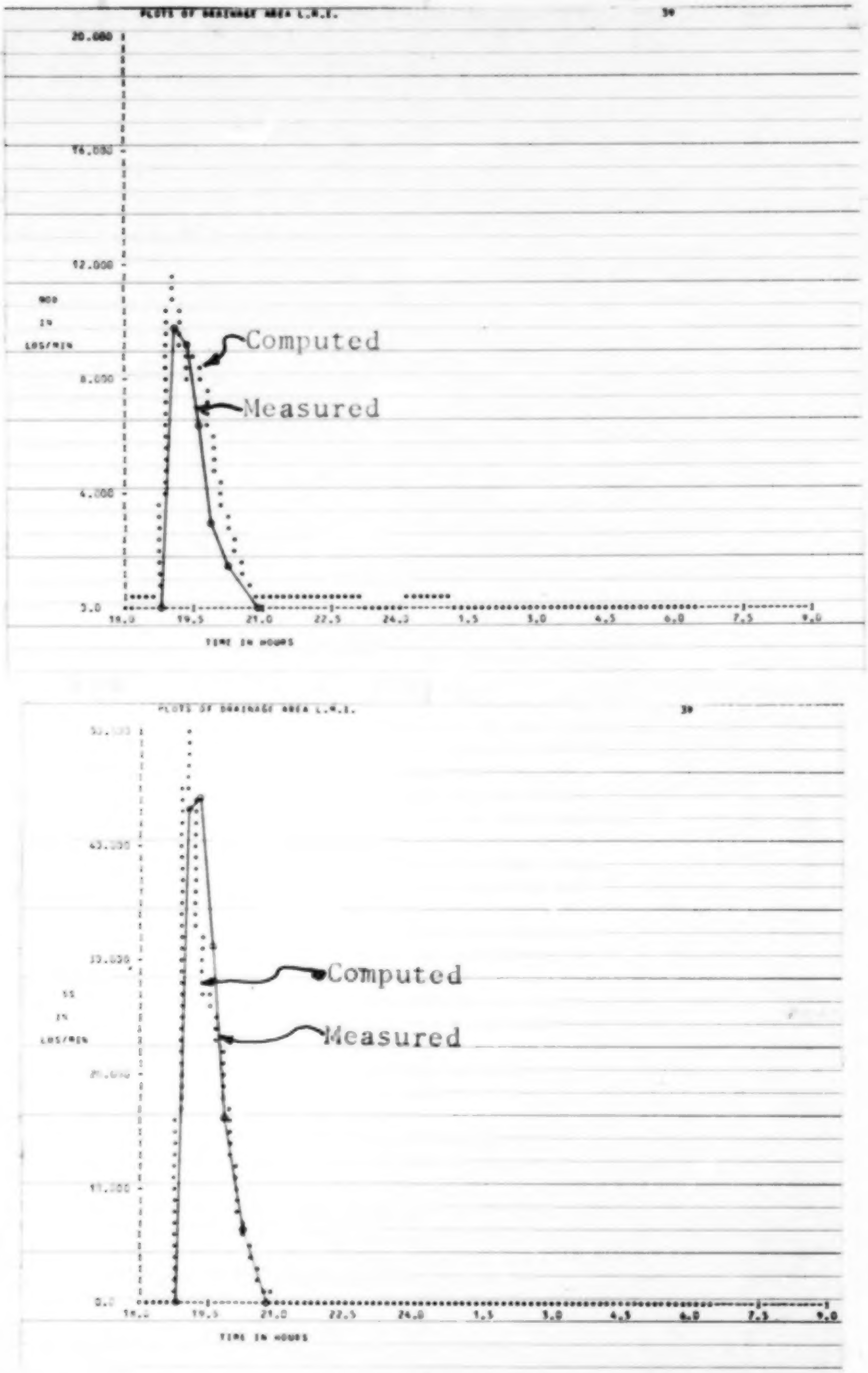

Figure B-10 Montrose Avenue Overflow Results - Storm of August 1, 1975

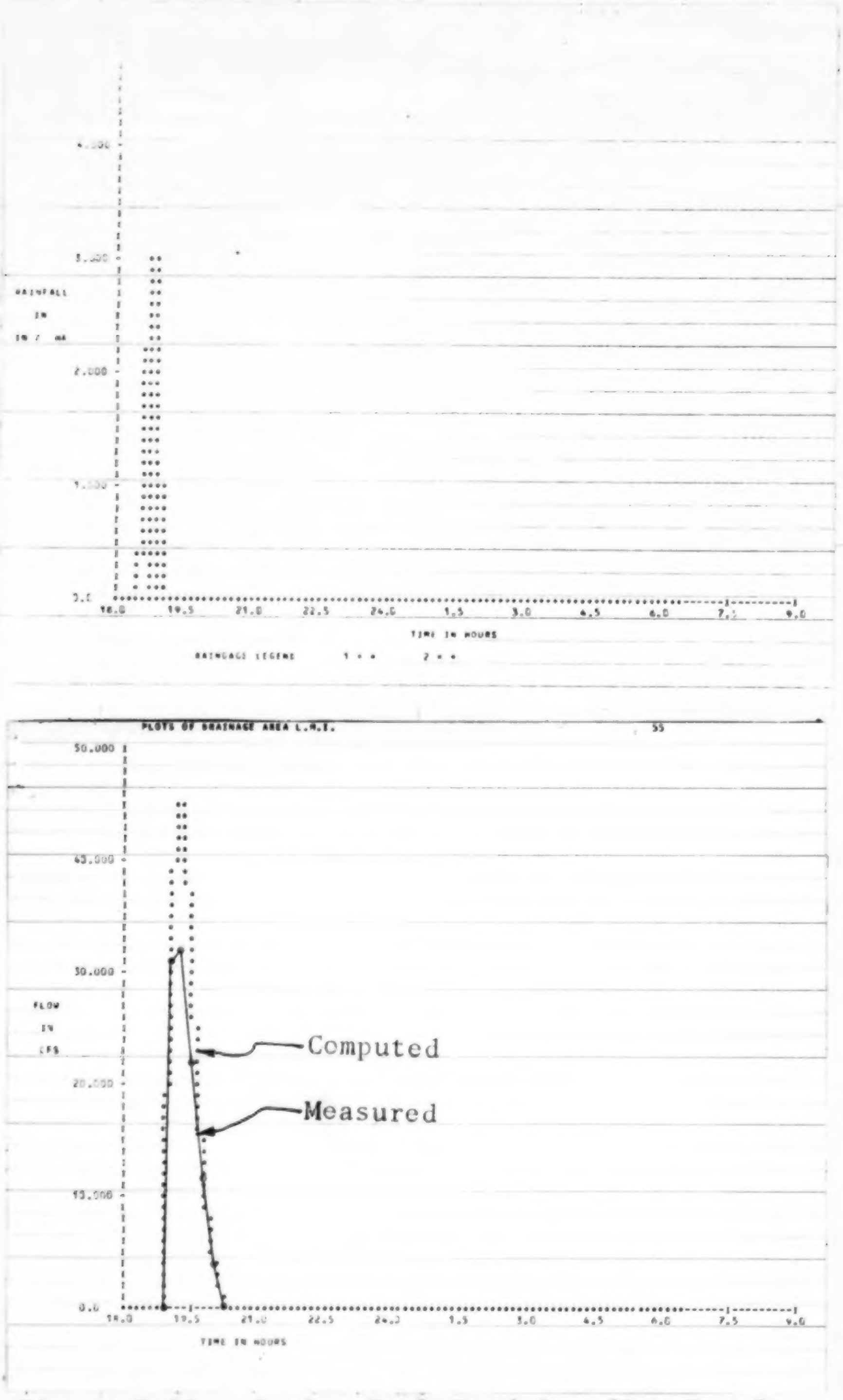

Figure B-11 Irving Park Road Overflow Results - Storm of August 1, 1975

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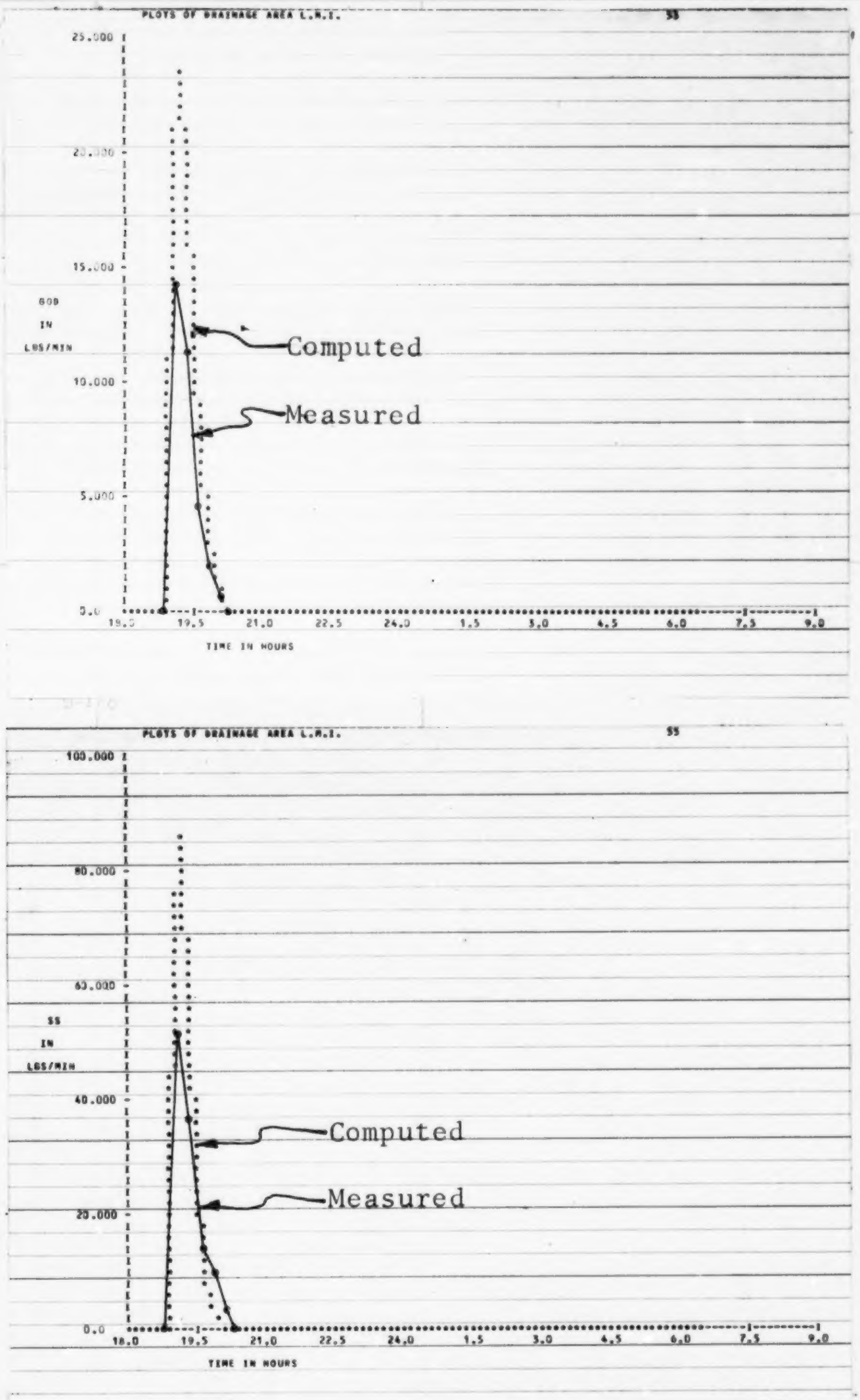

Figure B-12 Irving Park Road Overflow Results - Storm of August 1, 1975

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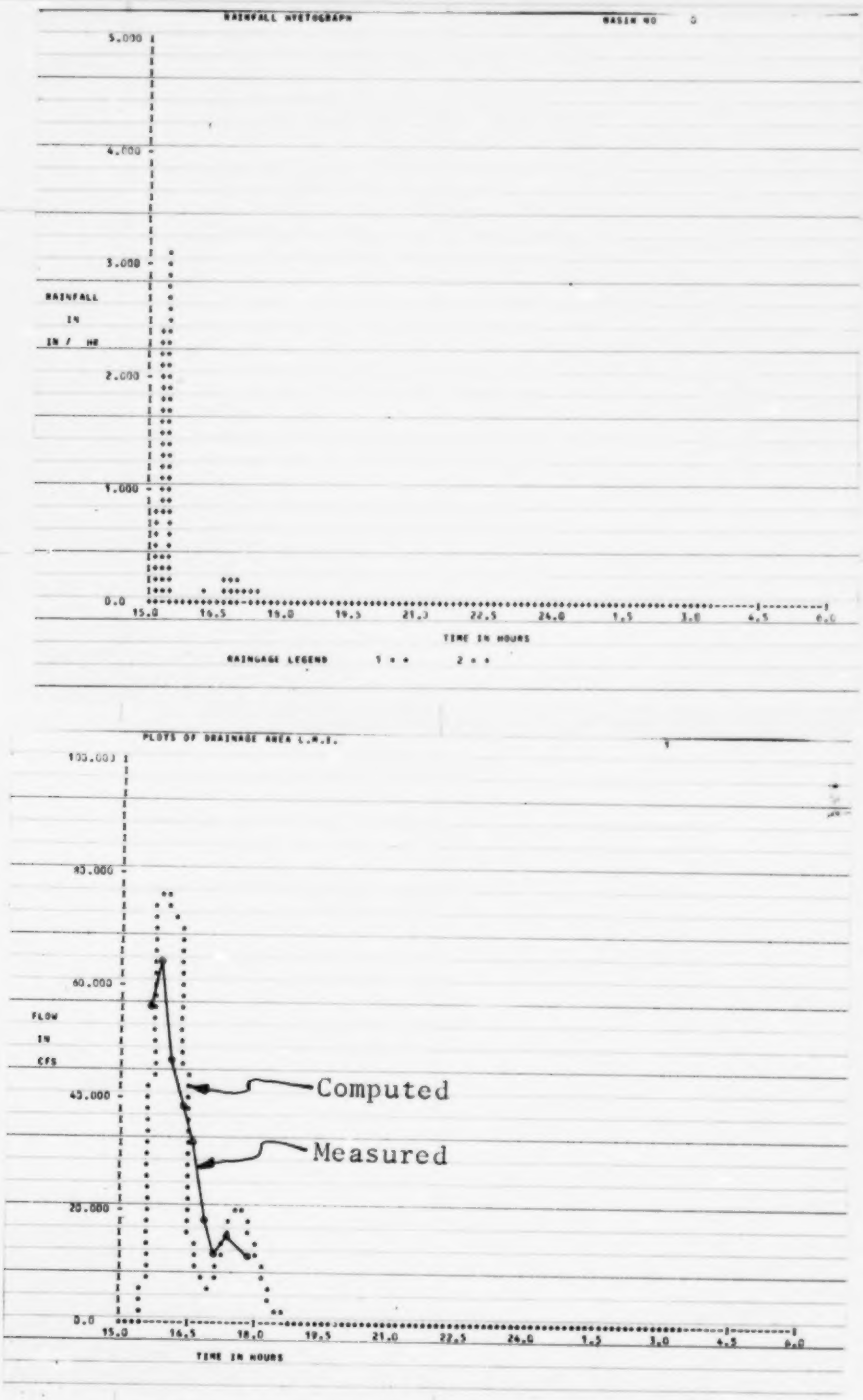

Figure B-13 Lawrence Avenue Overflow Results - Storm of August 11, 1975

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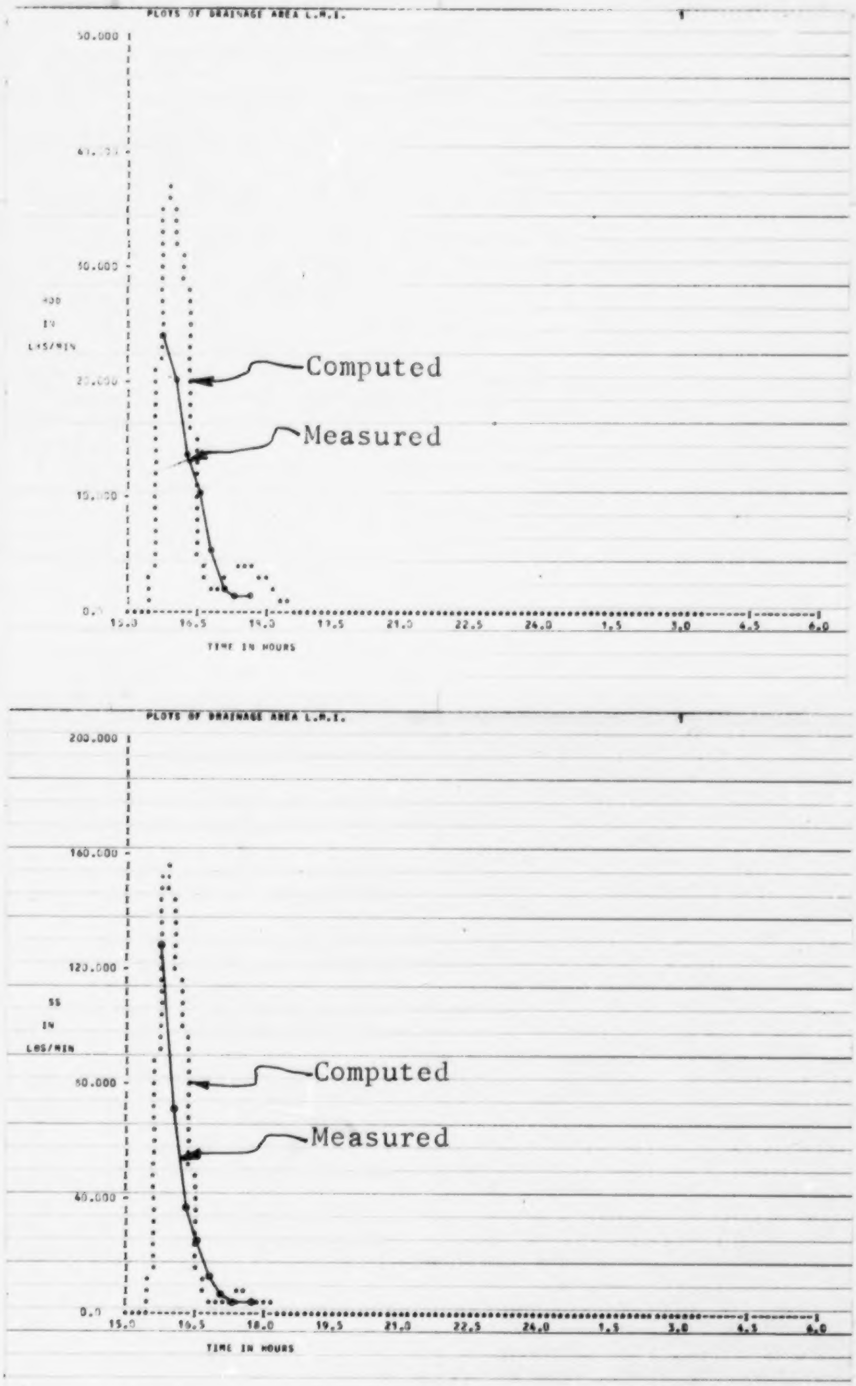

Figure B-14 Lawrence Avenue Overflow Results - Storm of August 11, 1975

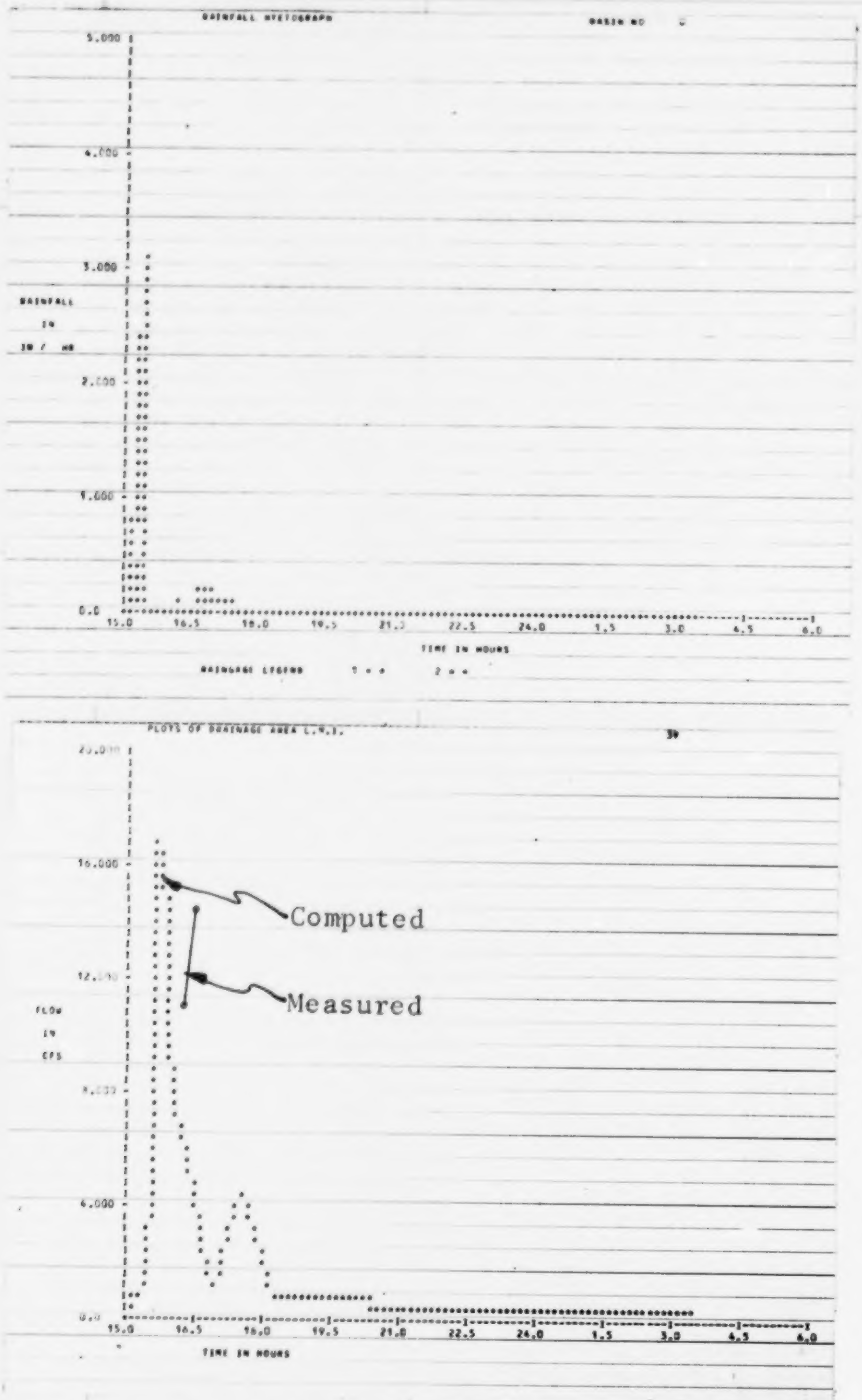

Figure B-15 Montrose Avenue Overflow Results - Storm of August 11, 1975

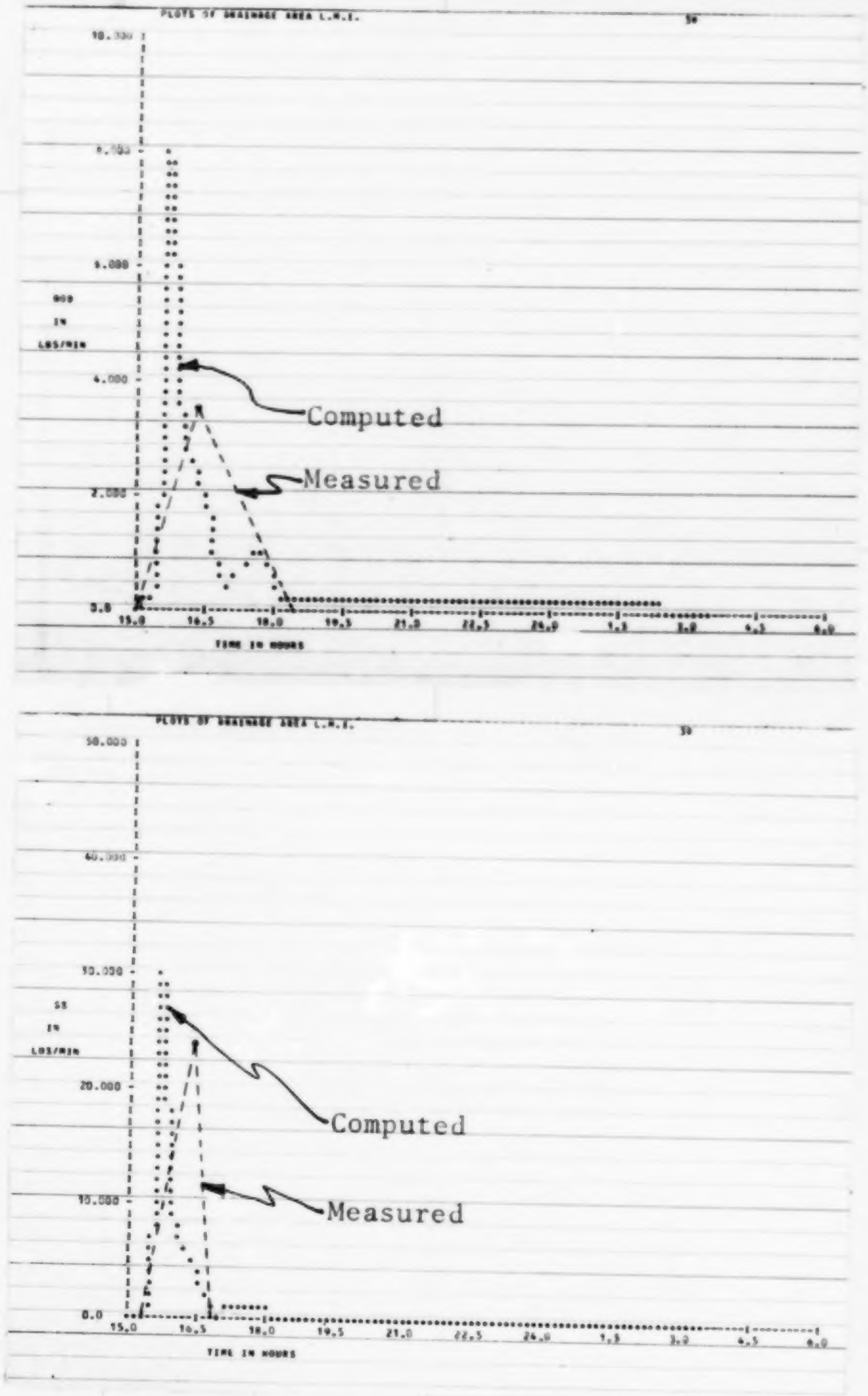

Figure B-16 Montrose Avenue Overflow Results - Storm of August 11, 1975

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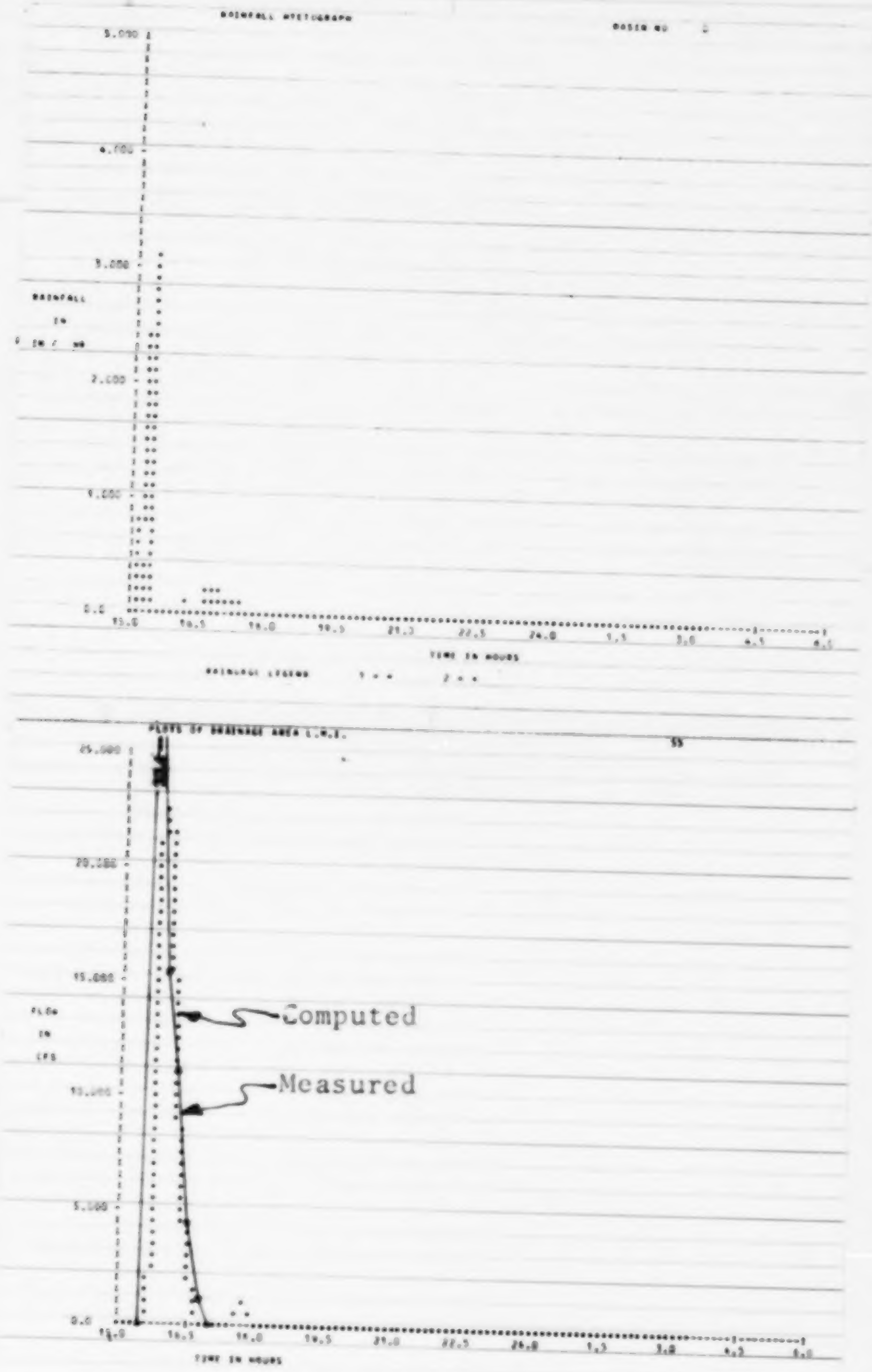

Figure B-17 Irving Park Road Overflow Results - Storm of August 11, 1975

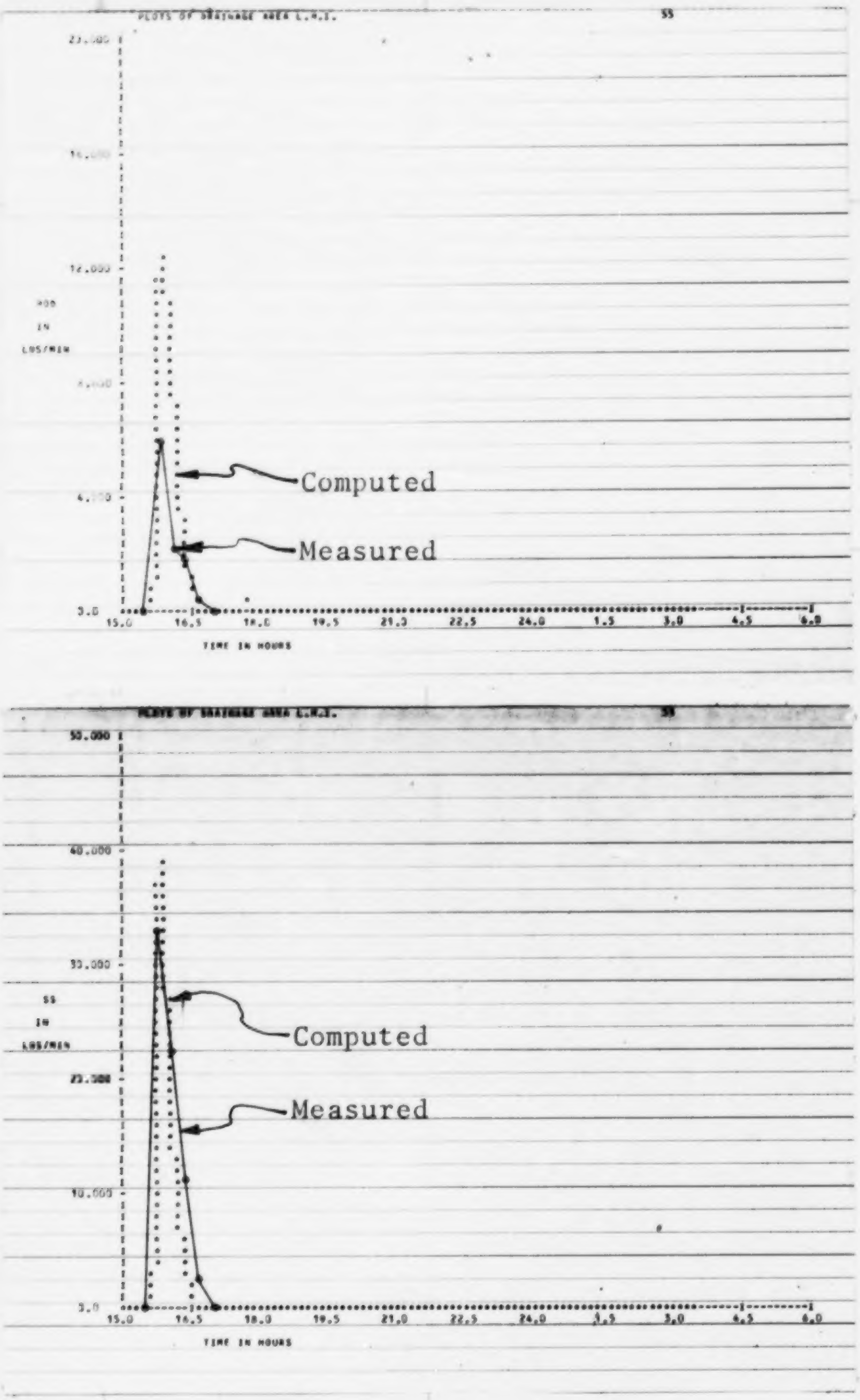

Figure B-18 Irving Park Road Overflow Results - Storm of August 11, 1975

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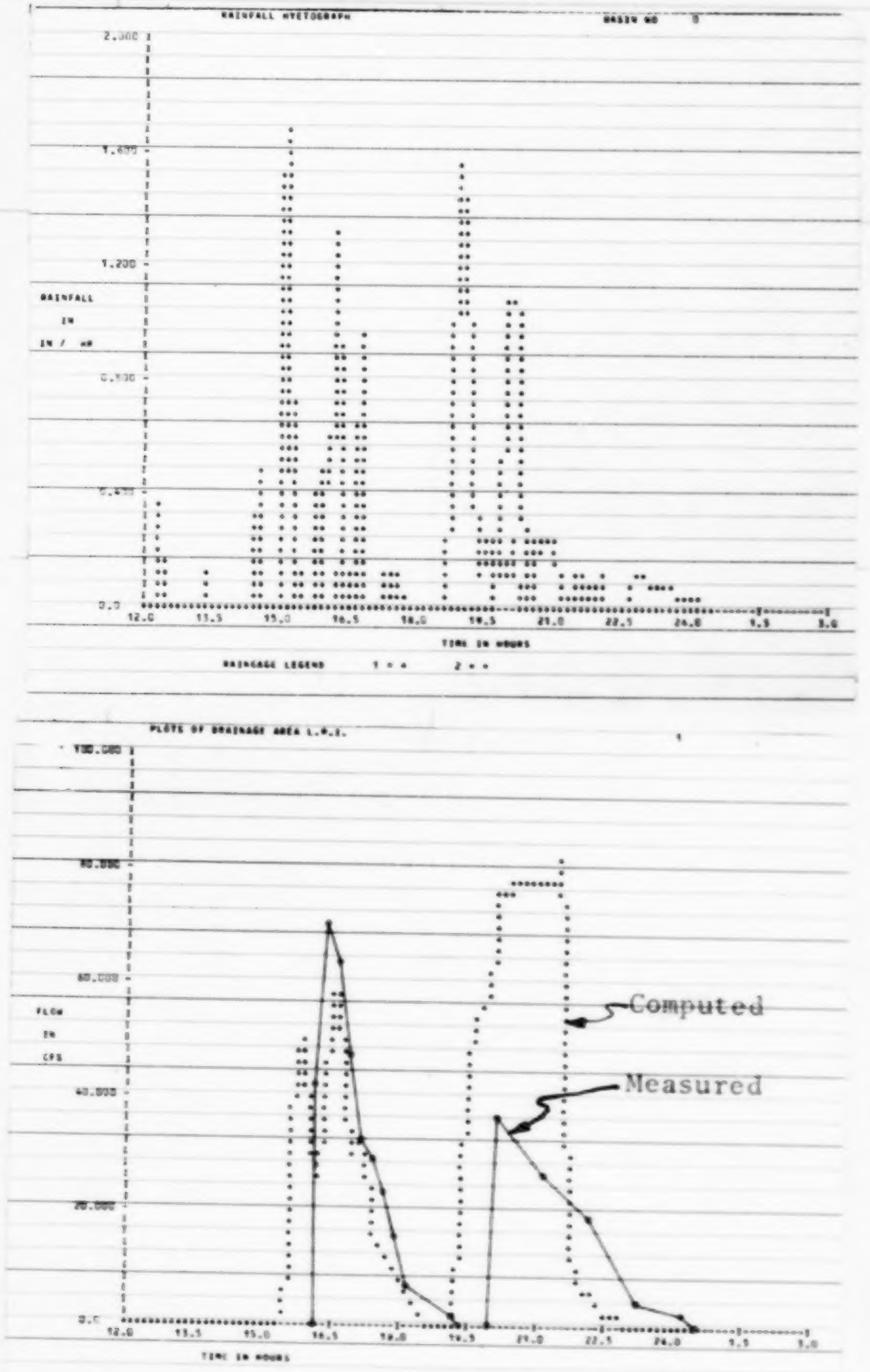

Figure B-19 Lawrence Avenue Overflow Results
Storm of October 24, 1975

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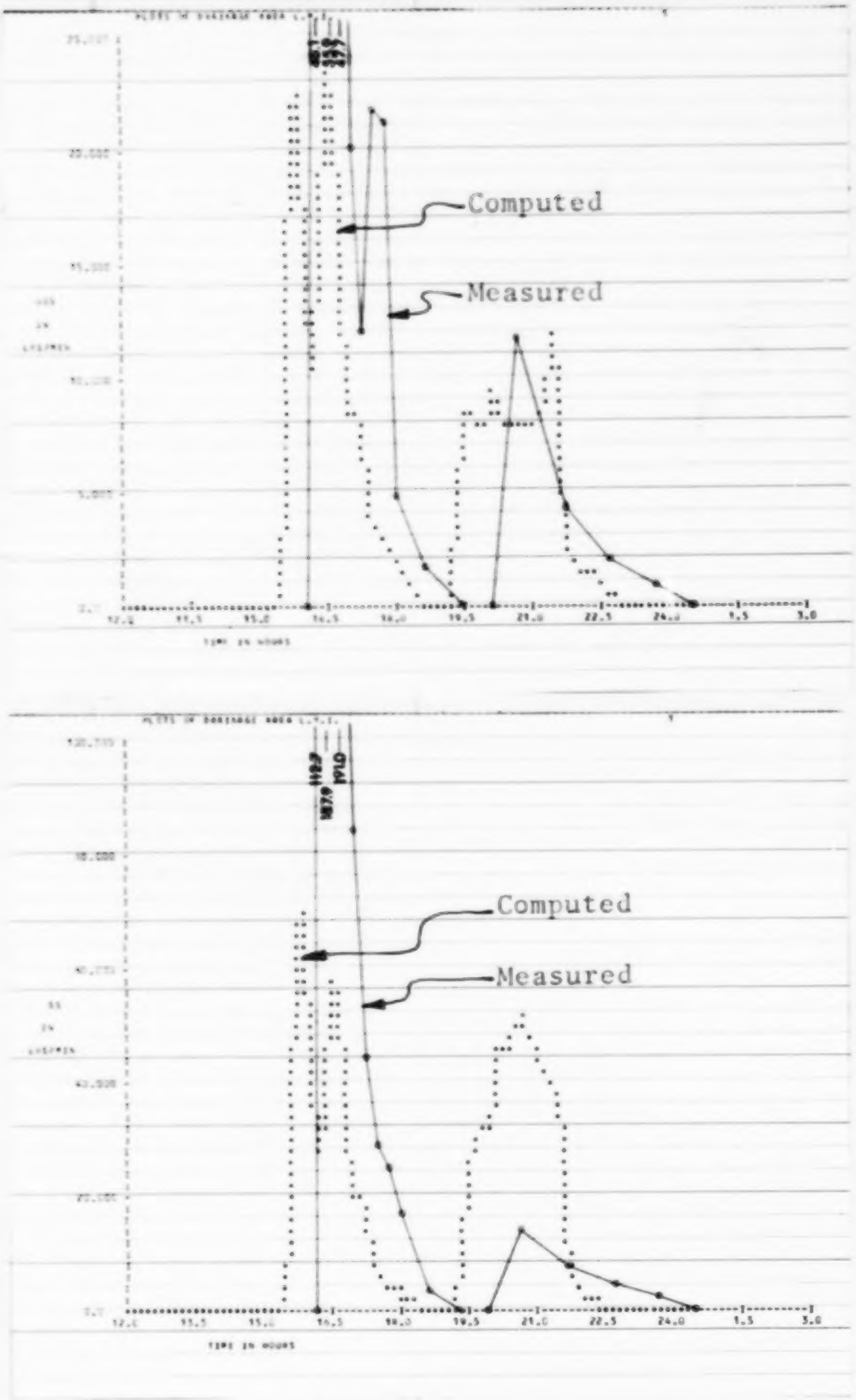

Figure B-20 Lawrence Avenue Overflow Results
Storm of October 24, 1975

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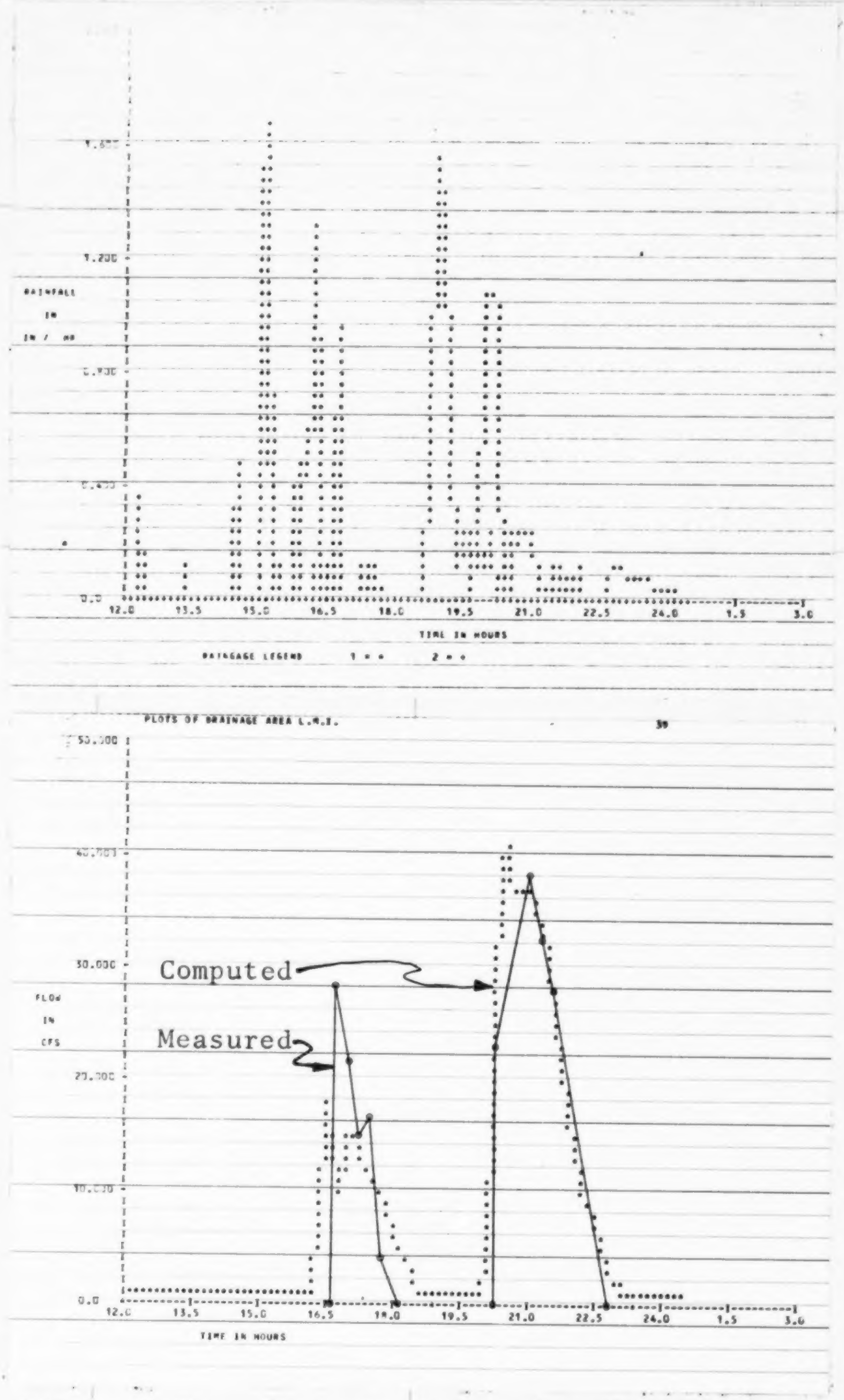

Figure B-21 Montrose Avenue Overflow Results
Storm of October 24, 1975

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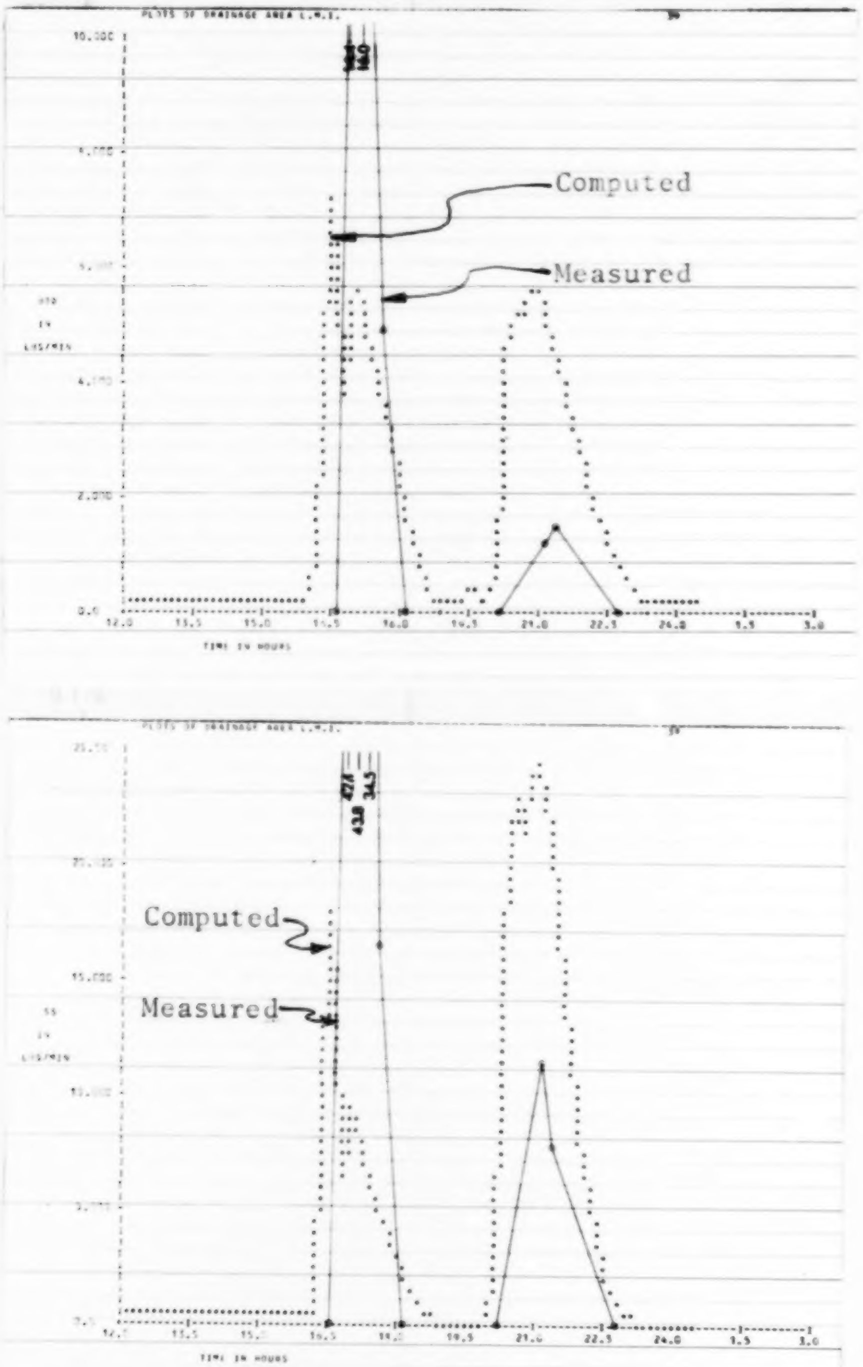

Figure B-22 Montrose Avenue Overflow Results
Storm of October 24, 1975

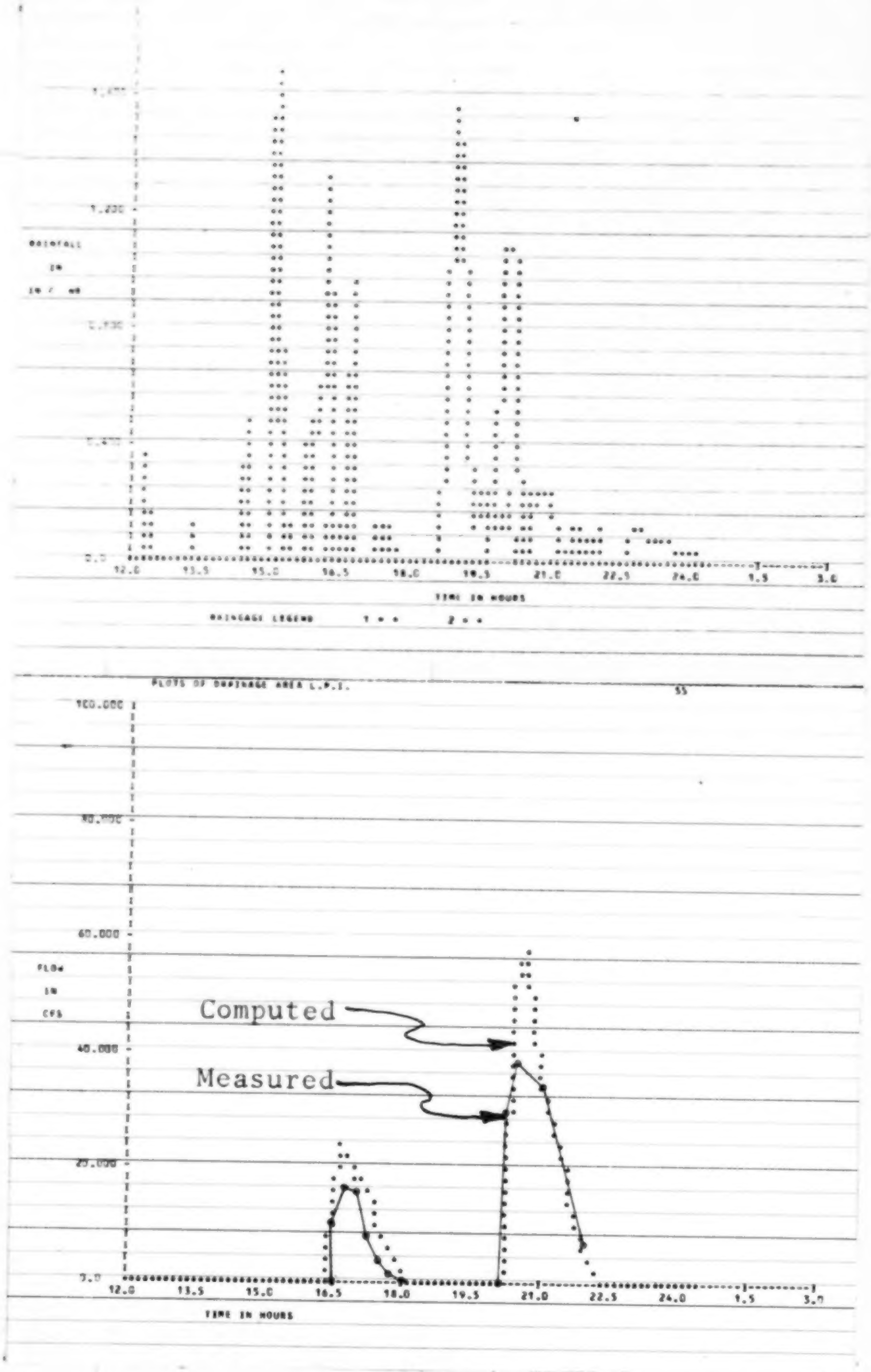

Figure B-23 Irving Park Road Overflow Results
Storm of October 24, 1975

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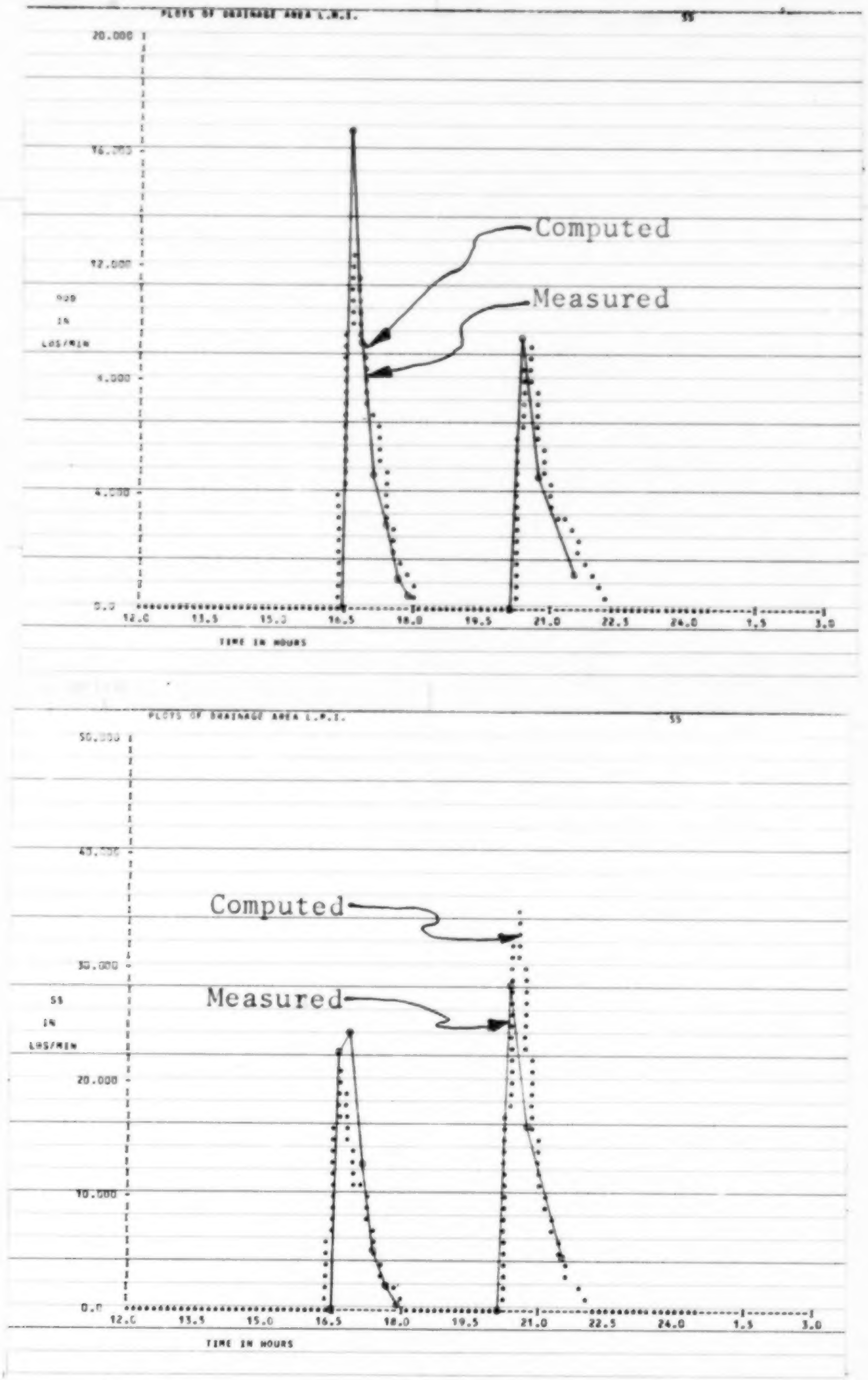

Figure B-24 Irving Park Road Overflow Results
Storm of October 24, 1975